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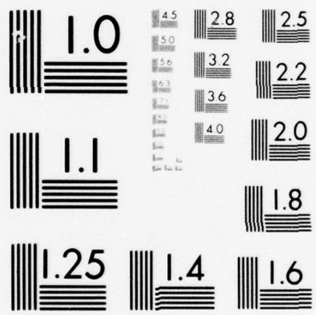

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KETRON, INC.

BUPERS MPN EXPENDITURE ESTIMATING
KFR 109-77
28 February 1977

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The Bureau of Naval Personnel has responsibility for controlling expenditure of the MPN funds and, in particular, for ensuring that this expenditure does not exceed the amounts annually authorized by the Congress. Forecasting the precise level and time of disbursements is a difficult task, because claims for payment arise at a great diversity of sites and reporting delays can vary considerable. To guard against the possibility of overspending, the Bureau of Naval Personnel has refrained from planning to spend next page

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the full sum allotted it by Congress, holding some monies back so that it can deal with unexpected obligations. It is clearly desirable that these reserve assets be kept to a minimum consonant with a desired level of protection against overexpenditure. The purpose of this study is to develop the analytical tools to estimate reliably the proper margin of safety that BuPers should maintain to guard against overspending.

The analysis of financial data of the BA(1) and BA(2) accounts of the past three fiscal years show that BuPers has exerted close control in keeping a proper relationship between actual expenditures and planned obligations. However, further refinements and improvements in the methods and procedures are possible.

The application of time series analysis to the three-year financial data has resulted in a model which has the potential to be used in forecasting expenditures, for BA(1) and BA(2) from planned obligations as established in the plan at the beginning of the fiscal year. Reserves may then be determined for various levels of statistical confidence to assure that actual expenditures will not exceed the forecasted expenditures plus the reserve.

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TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

The Bureau of Naval Personnel has responsibility for controlling expenditure of the MPN funds and, in particular, for ensuring that this expenditure does not exceed the amounts annually authorized by the Congress. Forecasting the precise level and timing of disbursements is a difficult task, because claims for payment arise at a great diversity of sites and reporting delays can vary considerably. To guard against the possibility of overspending, the Bureau of Naval Personnel has refrained from planning to spend the full sum allotted it by Congress, holding some monies back so that it can deal with unexpected obligations. It is clearly desirable that these reserve assets be kept to a minimum consonant with a desired level of protection against overexpenditure.

The purpose of this study is to develop the analytical tools to estimate reliably the proper margin of safety that BuPers should maintain to guard against overspending. Excessive reserves would represent an opportunity cost that could result in reduced levels of manning in the Navy.

The study contains three main sections. The first provides a written description of current procedures for monitoring and controlling expenditures. The second section is a preliminary analysis of the data; it is a first cut at defining what a reasonably safe size of the reserve would be. The final section presents a time series analysis of the data. Box-Jenkins techniques were used to explain the value of the Actual Expenditure for a given month in terms of the Actual Expenditure for selected previous months and the Planned Obligations for the given and past months; if one can explain this value satisfactorily, one can predict expenditures and hence the size of a reasonably safe reserve fund.

There are five appendices. Appendix A contains a comparison of yearly appropriation and expenditures for BA(1) and BA(2) during the period from 1961 to 1975. Appendix B is a set of flow charts which show in graphic form the material found in the Organizational Process section. Appendix C contains supportive material for the simple statistical analysis described in section four

of the report. Appendix D contains the detailed results of the time series analysis. Lastly, the six programs used for the Box-Jenkins analysis and a user's guide to these programs can be found in Appendix E.

The analysis of financial data of the BA(1) and BA(2) accounts of the past three fiscal years show that BuPers has exerted close control in keeping a proper relationship between actual expenditures and planned obligations. BuPers has maintained a reasonable margin of safety in those two accounts, ensuring that actual expenditures do not exceed planned obligations on a cumulative basis during the fiscal years examined. However, further refinements and improvements in the methods and procedures are possible.

The application of time series analysis to the three-year financial data has resulted in a model which has the potential to be used in forecasting expenditures, i.e., planned expenditures, for BA(1) and BA(2) from planned obligations as established in the plan at the beginning of the fiscal year. Furthermore, the analysis shows that actual expenditures in the BA(1) account for any year will not exceed the forecast expenditures by more than 9.1 to 13.9 million with a 95% level of confidence. These figures represent the margin of safety needed in the last three or six months of the year, respectively, when it is assumed no further adjustments may be made to the account to increase or decrease expenditures. Therefore, a reserve of between 9.1 to 13.9 million can be maintained to assure that the BA(1) account is not overspent. Part of this reserve, if not all of it, may already be maintained in the difference between cumulative forecasted expenditures from the model and total planned obligations. When this excess does not account for the total 9.1 to 13.9 million reserve needed, a small contingency may be left unobligated initially as an added reserve, a practice which is presently used by BuPers. However, should the difference between cumulative forecasted expenditures and planned obligations be larger than what is needed, a new plan of obligations can be used in the model to obtain a new forecast and an acceptable difference. Similarly, for the BA(2) account, the margin of safety to be added to the forecasted expenditures obtained from the model is between 20.4 and 28.8 million. An important caveat applies;

these margins of safety are realistic only if time series analysis is initiated within BuPers and continually updated as changes in policies and procedures occur. The model and its results hold only as long as the planned obligations and actual expenditures are consistent with the trend line observed from the three years of data. Changes in policy and procedures may cause a divergence from this norm. Also, within approximately six months of a given fiscal year, the data on actual expenditures are sufficient to show whether or not divergence from the trend line is occurring. If divergence is apparent, the trend line may need to be reevaluated and the forecasted results of the model examined further.

The discussion on operation procedures for BuPers and, in particular, Pers 3, represents an understanding that is essential for appropriate utilization of the models for time series analysis of BuPers data. These procedures should be updated and expanded to include in detail other divisions within BuPers, notably Pers 2 and Pers 223, that participate extensively in the MPN budget program. Should procedures for the determination of this data change, then the model must be changed in keeping with alterations made in procedures or processes. Procedural documentation then becomes a guideline for adjusting the model as well as a good historical record of organizational changes and sequential adaptations needed in the model. Updated records on processes, procedures and interactions between divisions also offer material for an efficient training program.

2. INTRODUCTION

The Bureau of Naval Personnel has responsibility for controlling expenditure of the MPN funds and, in particular, for ensuring that this expenditure does not exceed the amounts annually authorized by the Congress. Forecasting the precise level and timing of disbursements is a difficult task, because claims for payment arise at a great diversity of sites and reporting delays can vary considerably. To guard against the possibility of overspending, the Bureau of Naval Personnel has refrained from planning to spend the full sum allotted it by Congress, holding some monies back so that it can deal with unexpected obligations. It is clearly desirable that these reserve assets be kept to a minimum consonant with a desired level of protection against overexpenditure. The amounts withheld each year might actually be too small, so that it is by chance the Bureau has not overspent in the past due to unusually low unexpected obligations. It is equally possible that they might be too large, so that the Navy is not "buying" as many people as it might. No procedures have existed hitherto to predict what the proper level of the reserve should be.

In the past fifteen years this lack of a predictive apparatus has allowed BuPers to overspend a number of times. BA(1) was overspent in 1962, 1963, 1969, 1971 and 1972; BA(2) had overruns in 1966, 1969 and 1972. If a set of programs such as Ketron provides in an appendix to this report had been in use, then BuPers could have protected itself against these embarassments. Until procedures are adopted to estimate reliably the safety of a reserve, the possibility remains that overexpenditure will recur.

This study concentrates on two of the six Budget Activities with which the Bureau of Naval Personnel is concerned. Ketron has put its effort into developing estimators for reserves to BA(1) Pay and Allowances for Officers and BA(2) Pay and Allowances of Enlisted Personnel. Together, BA(1) and BA(2) account for 88% of the total MPN appropriation.

The data base from which Ketron's analysis proceeded consisted of two sets of figures. The first contained information from 1961 to 1975 on annual expenditures and authorization. The second, and more useful, set of data was the monthly record of FY 1974-1976 for Planned Obligations, Actual Obligations and Actual Expenditures. The years 1974-1976 were chosen because they are the only years for which monthly data are still available. Ketron also examined the monthly reports on strength.

The main body of this report contains three sections. The first provides a written description of the working of Pers 3, the portion of the Bureau which monitors and controls expenditure. It provides the foundation on which the remainder of the study is built. The second portion of the report is a preliminary analysis of the data; it is a first cut at defining what a reasonably safe size of the reserve would be. The final section presents a time series analysis of the data. Using Box-Jenkin's techniques, we tried to explain the value of the Actual Expenditure for a given month in terms of the Actual Expenditure for selected previous months and the Planned Obligations for the given and past months; if one can explain these values satisfactorily, one can predict the size a reserve fund needs to be if it is to be at a reasonably safe level.

This report is ended by five appendices. The first contains a comparison of yearly appropriation and expenditures for BA(1) and BA(2) during the period from 1961 to 1975. The second appendix is a set of flow charts which report in graphic form the material found in the Organizational Process section. Appendix C contains supportive material for the simple statistical analysis described in section four of the report. Appendix D contains the detailed results of the time series analysis. Lastly, the six programs used for the Box-Jenkins analysis and a user's guide to these programs can be found in Appendix E.

Ketron's results should be utilized with the understanding that they apply only so long as BuPers utilizes the present system of calculating obligations.

Our assumptions remain true given that the practices of the past three years continue in use. If there are any changes in the methodology employed by Pers 2 and Pers 3, or if there are policy alterations which affect the outcome of the procedure, the impact on our conclusions should be understood before BuPers uses them any further.

We are sincerely grateful for the help that Commander W.E. Henry, Edward Timko, Lorraine Lechner, Sue Lutz and Robert Lehto gave us in our attempt to understand the workings of the MPN account.

3. ORGANIZATIONAL PROCESSES

3.1 Introduction

This chapter presents a description of the responsibilities and processes of the Bureau of Naval Personnel for developing and maintaining the MPN budget for a given fiscal year. A review of total Department of Defense and Navy planning begins the discussion to provide the structural and monetary framework within which BuPers must operate. The discussion then focuses on a detailed look at the interaction of the various units within Pers 2 and Pers 3 as they prepare and revise the MPN budget for submission to Congress. The submission of the MPN budget to Congress ends BuPers' first phase of responsibility, that of the budget development.

The second half of this section describes in detail the processes and calculations that are used within Pers 3 to record and control obligations and expenditures throughout the current year. This half explains how units of Pers 3 control the budget with internal operating plans that are constantly revised, with calculations that reflect the trends of actual obligations and expenditures, and with limited freedom to move funds from one BA to another. All these procedures and calculations used within Pers 3 have been developed in an attempt to expend virtually all of the MPN appropriation each year without running the risk of exceeding it. At the end of this chapter one may find a summary of the responsibilities within Pers 2 and Pers 3.

All references made to titles such things as Pers 223 apply to organizations, not individuals.

3.2 Planning for Budget Submission

Planning for future military personnel expenditures is a dynamic process that requires careful analysis of historical data. To this end, the Department of Defense constantly quantifies and revises anticipated strength and monetary requirements to enable individual organizations within each branch of the service to budget and request funds from Congress each year. The Department of Defense begins planning as far as 10 years in advance so that a current fiscal year's requirements have been reviewed and revised many times. Input from

each branch of the service is submitted to DoD each year as they individually plan their future needs.

The Five Year Defense Program (FYDP) contains the anticipated personnel program for five years for all divisions within each military service. In January this plan shows the program for the coming fiscal year and the next four years. From the FYDP the Chief of Naval Operations extracts information concerning the Navy to begin the process of updating Navy expectations. Navy concerns for the future are incorporated in the Navy Planned Objective Memorandum (POM) which as in all the services is a five year plan updated every year. The CNO (OP-09-0) takes the figures for the last four years of the FYDP, builds in new requirements he foresees, and combines these years with the strength and monetary estimates of one additional year. The Navy POM is used in turn to update the new FYDP.

Using the relevant limitations outlined by the CNO, the MPN Planning Coordination and Execution Branch (Pers 223) in the Bureau of Naval Personnel (BuPers) begins to develop new estimates for its own budgetary concerns. Manpower estimates for enlisted personnel for each of the five years are provided to Pers 223 by the Enlisted Plans Branch (Pers 212) from its Inventory Projection Model (FAST). FAST gives these strength estimates by rating, paygrade and length of service. Similar information on officer manpower is provided to Pers 223 by the Officer Plans Branch (211). Financial Management and Management Information (Pers 3) provides the branch Pers 223 with the average pay rates for other than basic pay used in the most current MPN budget submission to Congress. With these strength estimates and average pay rates the branch Pers 223 uses its Cost Budget Model (BUCOMP) to determine total cost estimates for Military Personnel, Navy, MPN, for all five years of the new POM.

Once strength and monetary projections are reached that closely comply with the limitations set by the CNO, they are submitted to the CNO/NAVY COMPTROLLER who integrates all Navy input into the five year POM. The CNO/NAVCOMPT may request changes or make additional cuts to some programs before forwarding the new POM to the Secretary of the Navy, who can also alter the POM.

Finally, sometime in May, the Secretary of Defense receives and incorporates the Navy POM into his total defense plan. In so doing, he makes the final determinations concerning total projected cost for each branch of the service over the given five year period.

3.3 MPN Budget Preparation

Once the Secretary of Defense has determined the final cost estimations for the new FYDP, Pers 223 begins budget preparations for the next fiscal year. The yearly budget process approximates the process used in developing input to the PCM.

Within Pers 2 various options of monthly strength estimates are developed for the fiscal year using its strength planning models. These options are then reviewed within Pers 2 to ensure compliance with the following constraints.

1. End strength
2. Man-year averages
3. Dollar limitations
4. Recruitment cycle

(Items 1–3: established in PCM)

A constant strength total each month for a budget year is preferred but not entirely feasible. Those plans, however, that drastically diverge from a reasonably uniform estimate are discarded.

Strength plans that are not eliminated are submitted to Pers 223 to be costed by BUCOMP in order that the plan that best approximates monetary controls can be determined. As in the costing for the POM input, recent average pay rates for the model and tentative control dollar estimates for various categories are supplied by Pers 3. Average pay rates are discussed in detail in a following section.

The "best" strength plan along with cost estimates from the model are finally presented to Pers 3 for the first official budget calculations. Along with the monthly strength totals by paygrade, Pers 3 received man-year totals for most allowance categories. These man-year figures are first combined within Pers 2 from each program concerned with allowance payments. In some cases the programs are managed from offices within Pers 2.

Statistically derived data on enlisted allowance categories not obtained from Pers 2 are developed in Pers 3 from payroll information. A questionnaire is used to gather the information from a sample of five enlisted personnel stratum A random selection of disbursing officers within each stratum are requested to supply information on the number of days an entitlement is earned for a given

quarter for specific pay entitlement categories. An entitlement is any amount of pay a person is entitled to receive. In some instances, the total dollars given in payment are also requested for those categories that have variable rates for other than paygrade. The entitlements covered on the questionnaire include the following:

1. BAQ
2. Overseas Station Allowances
3. Sea and Foreign Duty
4. Enlisted Subsistence
5. Enlisted Clothing

Pers 3 enters the statistics from the questionnaires into a computer to obtain percentages, by paygrade, of the total population for the quarter of those entitled to each of the allowances. These percentages are calculated from the following formula:

$$\frac{\text{Weighted Average of Days Drawn in Each Stratum}}{\text{Total Number of Days for the Quarter}} \times \text{Weighted Average of \% Drawing in Each Stratum} = \text{Adjusted \% Drawing for the Quarter}$$

In each of the five strata the total days an entitlement is drawn and the percent drawing the entitlement are computed. A weighted average is then applied in both cases over all five of the strata to obtain the Weighted Average of Days Drawn and the Weighted Average of % Drawing which are needed in the formula. The adjusted percentages can be multiplied by total population sizes for each paygrade to determine the number of persons entitled to each allowance during the quarter. The population size for each paygrade is based on a weighted average of Manpower Management Information System (MAPMIS) end month strengths for the three months in the quarter and the month preceding the quarter.

With the information discussed in the paragraphs above, Pers 3 can begin costing strength estimates for the pay and allowance categories. To compute the budget year costs for all entitlements, Pers 3 now has at its disposal the following:

1. Monthly Strength Estimates by Paygrade and Years of Service from Pers 2, MAPMIS, or Joint Uniform Military Pay System (JUMPS).

2. Estimated manpower totals for most allowances from Pers 2.

3. Estimated percentages of total strengths entitled to all other allowances from Pers 3.

The monthly strength estimates by paygrade and years of service are used to develop the average pay rates and man-year averages that are found in the simple budget formulae that follow. Calculations of average pay rates are found in the following section:

Basic Pay

Average Pay Rates	X	Man-Year Averages	=	Total Base Pay by Paygrade for the year

Allowances for Which Number of Personnel is Known

Statutory Rate or Average Pay Rate	X	Man-Year Averages Entitle to Allowance	=	Allowance Costs for the Year (by Paygrade where Applicable)

Allowances for Which a Percentage has been Calculated

Percentage of Population entitled in each Paygrade	X	Man-Year Average	X	Statutory Rate or Average Pay Rate	=	Allowance Costs for the Year (by Paygrade where Applicable)

These equations are used to compute total costs for all entitlements by activity for the budget year.

3.4 Average Pay Rates

Average pay rates are calculated by Pers 3 continually throughout the year for all personnel by paygrade, using data that is supplied periodically from MAPMIS, JUMPS, or within Pers 2. The data can be expressed in matrix form by length of service (LOS) versus paygrade. Each cell or unit of the matrix contains a total average manpower figure corresponding to a given grade and LOS. MAPMIS and JUMPS supply actual manpower totals for enlisted personnel and officers respectively, while Pers 2 with its FAST model develops projections of manpower totals for the enlisted. Officer strength projections are determined by Pers 211 independently from historical trends.

Looking at one line in the matrix of LOS versus paygrade, the average pay rate for a given paygrade is calculated as follows:

End Strength Report for a Given Time Period by LOS	X	Pay Cell Rate (Statutory Rate)	=	Unit Dollar Value for the Given Time Period

$$\frac{\text{Total Dollar Value}}{\text{Total End Strength}} = \text{Average Pay Rate}$$

The total end strength figures in each cell of the matrix are multiplied by the statutory rate for the given paygrade and LOS. This gives a dollar figure. These dollar values are totaled for each line of paygrades and then divided by the end strength total for the line to give the average pay rate for each grade. Average pay rates are developed and reviewed monthly for enlisted personnel and officers. An average is taken of the average pay rates progressively developed in a given year to establish a new rate. This is especially important for use in the following year's budget preparation so that the pay rates to be used reflect an averaging out of major fluctuations in reported strengths and LOS of the previous year.

3.5 Revising the Budget

The first budget plan, Plan A, is prepared by Pers 3 in July and sent to the Secretary of the Navy/Navy Comptroller for the first review in August is called the NAVCOMPT Markup. Changes are requested and cuts in the total manpower and dollar figures are usually made. Pers 2 and 3 may appeal SECNAV/NAVCOMPT decisions with a reclama. Normally, Pers 2 and 3 will receive the SECNAV/NAVCOMPT decisions in August and revise Plan A according to the new limitations. This new budget plan, Plan B, is next submitted at the end of September to a joint review by OSD/OMB analysts. Pers 2 and 3 are then notified of budget changes in the form of PBD's -- Program Budget Decisions -- which are received until approximately the 15th of December. Again, Pers 2 and 3 may reclama any changes made in the review.

After the reclamas have been accepted or rejected, a second and usually final budget revision is done during the last two weeks in December. This re-

vision called Plan C is sent to Congress through OSD during the first week of January. It should be noted that the development of the three plans comprises the normal reviewing process. However, during certain budget years other reviews have been authorized before its submission to Congress. The President can also intervene in the process.

3.6 Management of the MPN Account

After Congress passes the MPN appropriation, BuPers prepares and submits a fund allocation request, or form 1105 to OMB via NAVCOMPT and the DoD Comptroller. Form 1105 requests monies in specific quarterly amounts and is supported by a detailed Financial Plan showing how BuPers plans to obligate the full amount provided it by Congress.

When OMB receives the Form 1105, it has several options to consider. It can approve the document as it stands, it can withhold funds from specific BAs, or it can simply keep back a sum from the entire MPN account. Funds are withheld from the MPN account for such reasons as OMB recognition that changed circumstances no longer require expenditure of certain funds. Monies withheld by OMB can be kept up to the beginning of the final quarter in the fiscal year, at which point they must be allocated or returned to Congress. Of course, if a demand for them arises before that time, they can be released as needed.

After BuPers receives an approved From 1105 from OMB, the Chief of Naval Personnel identifies a certain amount of money as a "contingency" against unplanned obligations or expenditures. The contingency is however not held separately in an official reserve. Its only difference from the other funds is that explicity plans are made not to expend it. Prior to FY77, the DoD MPN budget was not approved until well into through the fiscal year. A contingency has to be held against the possibility of Congressional cuts. As long as Congress passes the appropriation before the beginning of the fiscal year, there no longer is any need for this particular contingency. When the use of JUMPS is fully adjusted to Navy needs, BuPers anticipates that the contingency can be further minimized. When this eventually occurs, JUMPS will provide entitlement information previously unavailable from MAPMIS, and therefore enable more accurate forecasting.

Once the Chief of Naval Personnel identifies the contingency, Pers 2 draws up an Operating Plan, or Op Plan, detailing the monthly strengths of each paygrade in the Navy. Again, it uses the same models as in making the budget plans to cut strength estimates to within the limits ChNavPers places on them. Pers 2 then sends the Op Plan to Pers 3.

Pers 3 uses the Op Plan to develop plans both for monthly obligations and expenditures. Planned obligations are obtained by multiplying Pers 2's planned strength by paygrade with pay factors utilized in the budgeting process. Some estimates of those personnel entitled to specific allowances are not provided by Pers 2 and must be derived from the results of a stratified sample of pay records. When the use of JUMPS is operating smoothly, it will replace the pay records sample as a source of this information.

Expenditures are planned to within one percent of obligations with account being taken of monthly or seasonal fluctuations based on historical information. For instance, it is known that many officers retire early in the summer, so that expenditures for separation pay in BA1 will increase sharply at that time.

3.7 Budget Execution

In the monthly budget execution process Pers 3 is required to put on its ledgers a figure for the amount it has obligated to pay Navy personnel. This may not be changed once it has been recorded, but adjustments can be made in subsequent months. Because of the time lag introduced into Pers 3's calculations by the personnel reporting system, it is necessary to reevaluate amounts obligated periodically to ensure that cumulative obligations represent reported manpower.

To discuss budget execution properly, it is necessary first to define three terms: advance obligations, final obligations, and actual obligations. Having done this, we can then turn to a description of the process. In the discussion below M represents the month for which calculations are being computed, M-1 signifies the previous month, and M+1 stands for the following month.

Advance obligations are the last estimated obligations for month M. They are determined by addition of month, M-1's reported end strength to month M's planned end strength as found in the Op Plan. This sum is then divided by two and multiplied by

the "pay factors." These pay factors are the same as the average and statutory pay rates described in another section of this paper. Expressed in a formula:

$$\frac{\text{Reported end strength}_{M-1} + \text{Planned end strength}_{M}}{2} \times \text{Pay Factors} = \text{Advance Obligations}$$

The final obligation of month M is the second expression used in the determination of the actual obligation. It is calculated by adding together the monthly end strengths for months M and M-1, dividing by two and multiplying the quotient by the pay factors. In a formula, this would appear as:

$$\frac{\text{Reported end strength}_{M-1} + \text{Reported end strength}_{M}}{2} \times \text{Pay Factors} = \text{Final Obligation}$$

The actual obligation for month M is the figure which Pers 3 places on its General Ledger. It is the amount, *for legal purposes*, which the Navy has obligated during month M. It is found by subtracting month M-1's advance obligation from month M-1's final obligation and adding the remainder to month M's advance obligation. In formula form:

$$(\text{Final obligation}_{M-1} - \text{Advance obligation}_{M-1}) + \text{Advanced Obligation}_{M} = \text{Actual Obligation}_{M}$$

The monthly budget routine operates in the following manner. At the end of month M, the M-1 reported end strength from MAPMIS comes to Pers 3. In the middle of month M+1, month M's advance obligation is determined for the purpose of calculating its actual obligation. As seen above, the advance obligation is altered to take into account any amount over or under planned when the month M-1 advance obligation was calculated. The correction for errors in planning in month M-1 are made in month M because, as we have said, month M-1 actual obligation is a legal figure and may not be altered. At the end of month M+1 the end-strength report for month M arrives at Pers 3; it then calculates month M's final obligation for later use.

The accounting system for expenditures is similar to that for obligations. Expenditures for a given month are its actual expenditures reported to Pers 3 in the following month via the centralized Expenditure and Reinbursement Processing System (CERPS). These reports give only a grand total for each Budget Activity, Per 3 get no further detail on expenditure from the financial system than this,

and must accept these figures as accurate for the month reported, whether or not they are in error. If there are mistakes or if there has been a lag in processing pay reports, the adjustments will be embodied in the CERPS report and in the recorded actual expenditures for the following month.

In a cyclic process that is coincidental with the budget plan generation, BuPers revises its operational financial plans employing a procedure known as "zeroing out." Pers 2 generates a new Op Plan, altering its monthly strength plans in the light of what has already happened that fiscal year so that it can reach the end-of-the-year strength goal. Pers 3 takes the new plan and replans all the remaining monthly obligations; it takes into account what has already been spent that year. The generation of these new plans follows the same procedures as those described above which are used in the entire planning process.

3.8 Movement of Funds between Budget Activities

Beside "zeroing out", Pers 3 has a limited capability for adjusting its plans to meet unforeseen expenditures by moving funds from one budget activity to another.

There are two cases which are described below.

1. When the amount by which the BA total is altered is to be less than 5 million, Pers 3 possesses the authority to shift up to this amount from one BA to another without reference to Congress.

2. When the amount by which the BA total is altered exceed 5 million, Per 3 will submit a reprogramming request to Congress detailing why this must be done. Congress does not always approve these shifts. When Congress does not approve reprogramming, BuPers must compensate through program changes. In both cases these shifts apply only to the difference between the planned obligations and the amount appropriated by Congress in that BA for the year.

A SUMMARY OF THE RESPONSIBILITIES OF PERS 2 AND PERS 3 WITH REGARDS TO THE MPN ACCOUNT

The following are the responsibilities of Pers 2:

- Projects enlisted manpower totals with the use of the FAST model.
- Projects officer manpower totals from historical trends.
- Receives and forwards to Pers 3 man-year totals for most allowance categories.
- Prepares operating plan.
- Periodically revises operating plan as actual monthly end strength totals are received.

The following are the responsibilities of Pers 3:

- Develops average pay rates and tentative dollar controls.
- Calculates the costing for yearly budgets.
- Collects statistics on manpower totals for some enlisted allowance categories from payroll information.
- Develops monthly planned obligations and planned expenditures from the operating plan.
- Executes and monitors the budget by calculating advanced obligations, final obligations, and actual obligations.
- Periodically revises the plan of planned obligations for each revision of the operating plan.

4. ANALYSIS OF DATA ON A FISCAL YEAR BASIS

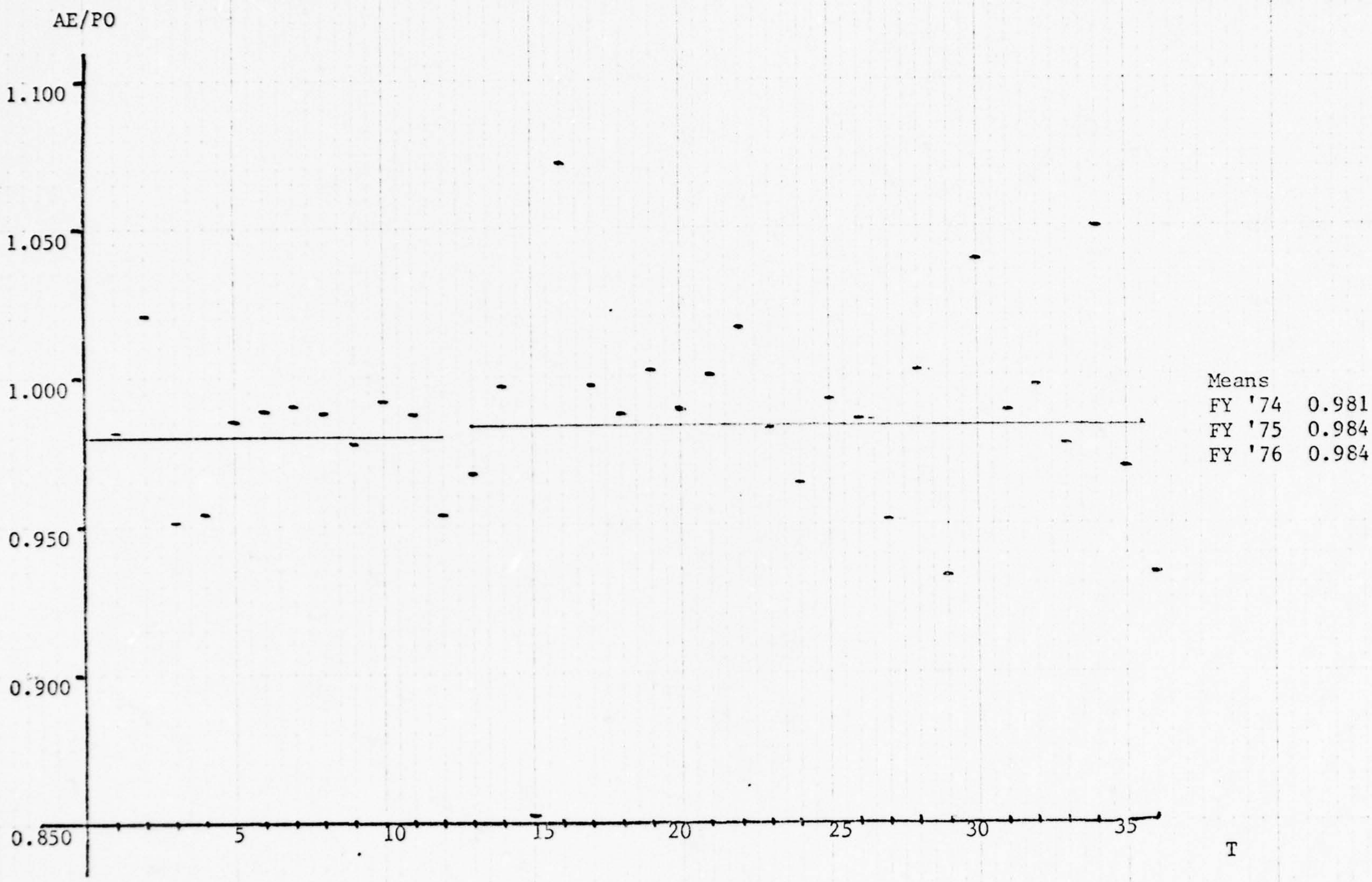
4.1 Introduction

In order to understand and define the problem facing BuPers each year to have expenditures approximate planned obligations without exceeding them, we derive the following results from a preliminary statistical analysis. These results offer a test or comparison against the findings and conclusions of the time series analysis. Details of the procedures used to obtain the equations and results here are given in Appendix C.

4.2 Relation of Actual Expenditures to Planned and Actual Obligations

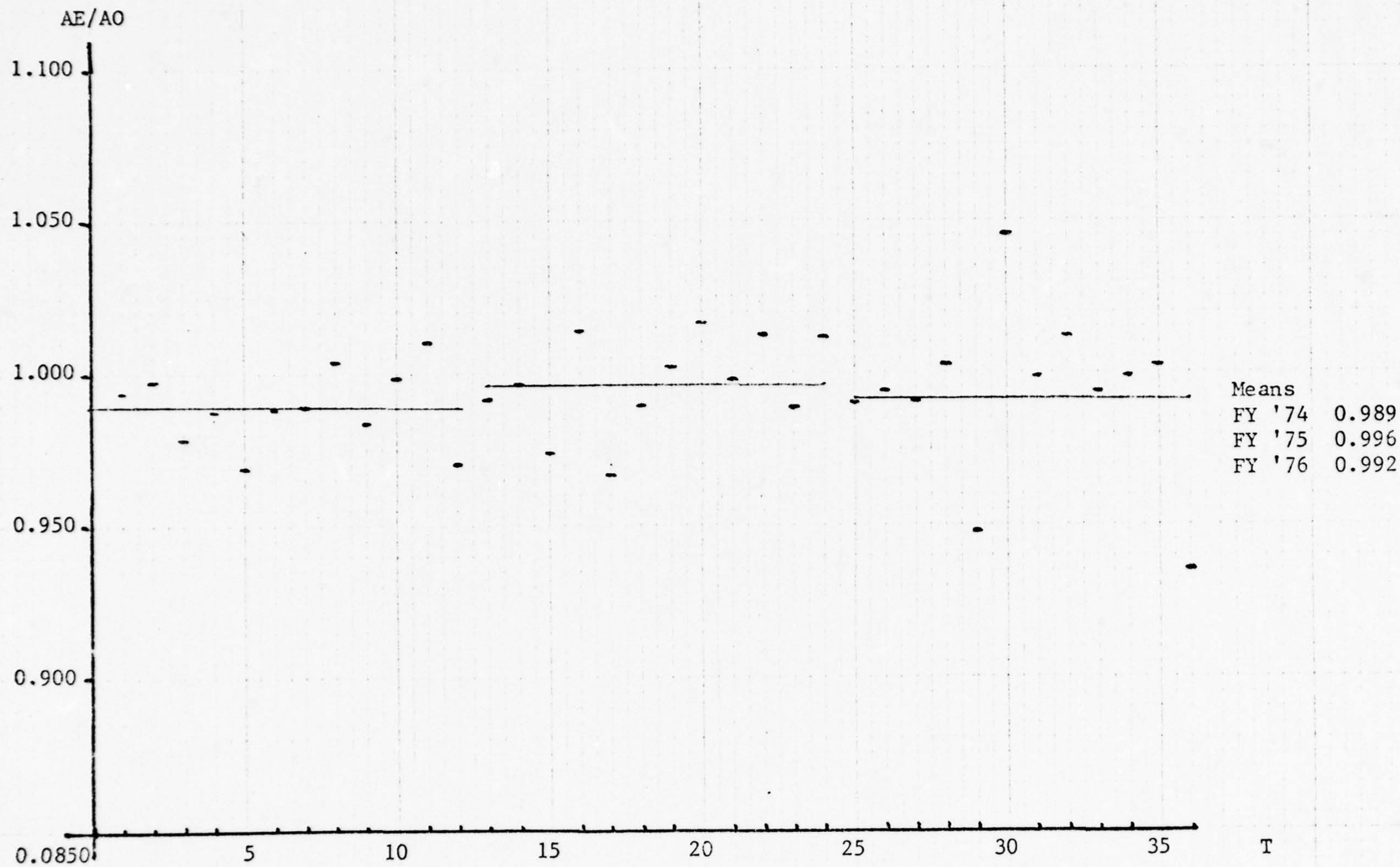
The purpose of controls on the personnel accounts is to prevent actual expenditures from exceeding the planned obligations dictated by Congressionally imposed ceilings. This purpose notwithstanding, it is desirable that the difference between actual expenditures and planned obligations be kept as small as possible, of course within limits that actual expenditures do not exceed planned obligations over the period of the fiscal year. Month-to-month variations, where actual expenditures frequently are in excess of planned obligations, are not of direct concern as long as the cumulative balance at all times is positive. A significant margin of planned obligations over actual expenditures represents unexpended funds that need not have been reserved.

In order to examine the relationship between expenditures and obligations on a fiscal year basis, the data from the 36-month period covering FY 1974 through FY 1976 are presented in Figures 4.1, 4.2, 4.3 and 4.4 in the form of ratios of actual expenditures to planned obligations and to actual obligations for the BA 1 and BA 2) accounts, respectively. The graphs show that while the monthly variations occasionally deviated more than 5% from the fiscal year mean, the means for each fiscal year showed relatively small variation. Particularly noteworthy is the observation that for both BA 1 and BA 2 the ratios of actual expenditures to planned obligations were consistently between 0.98 and 0.99 for each fiscal year. (See Figures 4.1 and 4.3). Supporting data for Figures 4.1 through 4.4 are provided in Appendix C.



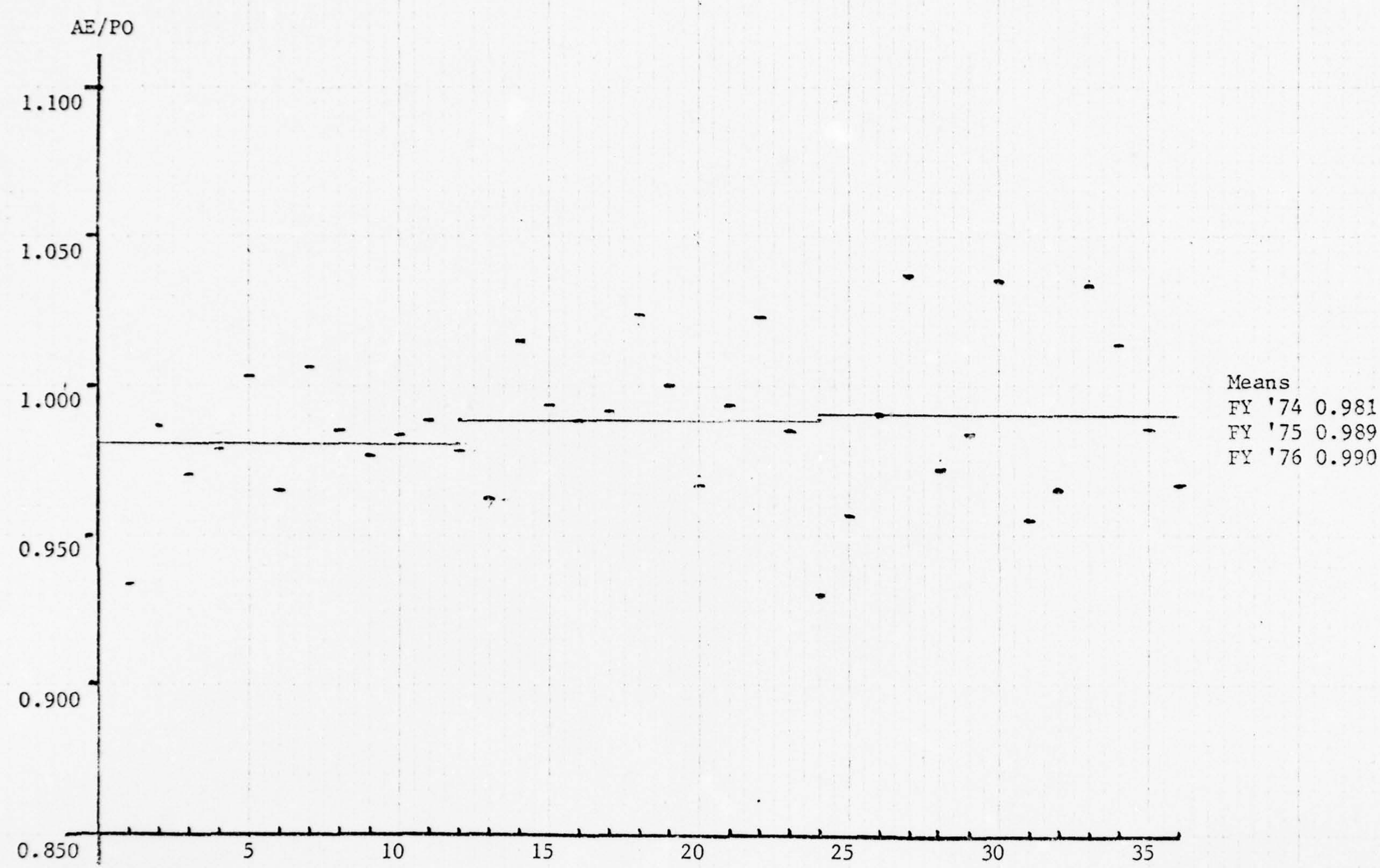
BA 1 Ratio of Actual Expenditures to Planned Obligations

FIGURE 4.1



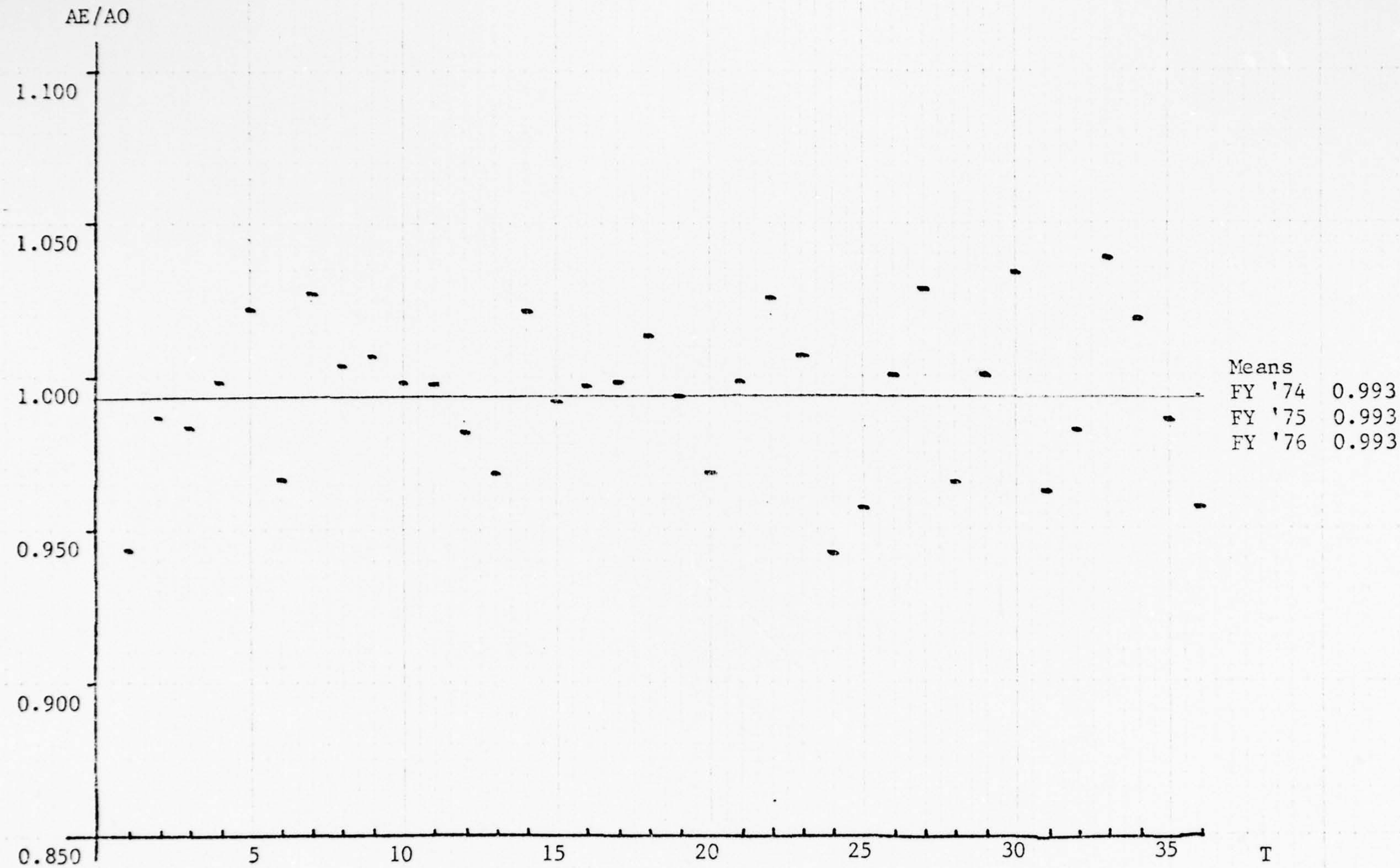
BA 1 Ratio of Actual Expenditures to Actual Obligations

FIGURE 4.2



BA 2 Ratio of Actual Expenditures to Planned Obligations

FIGURE 4.3



BA 2 Ratio of Actual Expenditure to Actual Obligations

FIGURE 4.4

TABLE 4.1
MPN ACCOUNTS FOR FY 74, FY 75, FY 76
($ Millions)

(BA 1)	Planned Obligations (PO)	Actual Obligations (AO)	Actual Expenditures (AE)	AE/PO	AE/AO
FY74	1282.0	1271.5	1257.0	.98050	.98860
FY75	1330.0	1313.0	1308.3	.98368	.99642
FY76	1355.0	1343.9	1333.0	.98376	.99189
(BA 2)					
FY74	3713.0	3667.6	3640.7	.98053	.99267
FY75	3820.0	3803.3	3777.2	.98880	.99314
FY76	3800.0	3787.2	3761.6	.98989	.99324

Using the data for the BA(1) account from Table 4.1, we have:

$T_1 = .98050$

$T_2 = .98368$

$T_3 = .98376$

$\overline{T}_2 = .98265$

$S_T{}^2 = .000003$

$S_T = .00186$

$S_T/\sqrt{3} = .001075$

where:

T_1 is the ratio of cumulative actual expenditures to cumulative planned obligations for FY 74, T_2 for FY 75 and T_3 for FY 76. $\overline{T}$ and $S_T{}^2$ are the sample mean and sample variance, respectively.

With a 90% probability the true mean μ of the total population, considered to be normally distributed, lies in the following interval:

$$.98265 - (t^{n-1}_{.05})(S_T/\sqrt{n}) \leq \mu \leq .98265 + (t^{n-1}_{.05})(S_T/\sqrt{n})$$

where:

n is the sample size and $t^{n-1}_{.05}$ the 90% confidence interval for the Student-t distribution. Since we have a sample size of 3, the estimate of the variance, $S_T{}^2$, has 2 degrees of freedom and $t^{2}_{.05} = 2.92$.

It follows that:

$$.98265 - 2.92\,(.001089) \leq \mu \leq .98265 + 2.92\,(.001089)$$

or

$$.97947 \leq \mu \leq .98583 \text{ (BA 1)}.$$

The probability that a future year's ratio (x_f) of actual expenditures to planned obligations will be less than the upper bound of the range for the population mean given above can be expressed as

$$P(x_f \leq \bar{T} + t^{(2)}_{.05} \left[\frac{S_T}{\sqrt{n}}\right]).$$

This probability is equal to .859.

To ensure with a .90 probability that our future ratio (x_f) lies within a given range, we must expand the range given for μ by multiplying the term containing $t_{.05}$ in the interval by $\sqrt{n+1}$.

Thus, the probability that a future ratio, x_f, will be in the following range is .90.

$$.98265 - (\sqrt{n+1})\,(t^{n-1}_{.05})\,(S_T/\sqrt{n}) \leq x_f \leq .98265 + \sqrt{n+1}\,(t^{n-1}_{.05})\,(S_T/\sqrt{n})$$

or

$$.97629 \leq x_f \leq .98901$$

Similar calculations for BA (2) account yield:

$T_1 = .98053$

$T_2 = .98880$

$T_3 = .98989$

$\bar{T} = .98641$

$S_T^2 = .000026$

$\frac{S_T}{\sqrt{3}} = .00300$

$$.98641 - \sqrt{n+1}\,(T^{n-1}_{.05})\,(S_T/\sqrt{n}) \leq x_f \leq .98641 + (\sqrt{n+1})\,(t^{n-1}_{.05})\,(S_T/\sqrt{n})$$

$$.96889 \leq x_f \leq 1.00393$$

Thus, three years of historical data implies that the upper limit of actual expenditures of the BA(1) account at the 95% confidence level[1/] is 1.1% less than the planned obligations for the fiscal years 1974 through 1976. In other words, on the average, in 19 cases out of 20 actual expenditures would be at least 1.1% less than planned obligations for the fiscal year, assuming the underlying distribution remains unchanged. A margin of safety of roughly 1.1% has thus been provided by the conservatism in the estimation of actual expenditures.

The historical experience of the past three fiscal years for BA(1) can be extrapolated with the caveat that the underlying system does not change. Actual expenditures can increase relative to planned obligations by 1.1% and the financial manager can be confident at the 95% level that expenditures will not exceed obligations.

For BA(2), however, the past three fiscal years indicate that no conservation in the estimation of actual expenditures is present. Instead, actual expenditures should be reduced by approximately .4% of planned obligations to ensure a probability of .95 that future expenditures will not exceed obligations.

The BA(1) account averages roughly $1300 million for each fiscal year. The difference of 1.1% between planned obligations and actual expenditures translates into about $14.3 million for the BA(1) account per year. The analysis for the BA(2) account indicates that actual expenditures should be reduced by .4% relative to planned obligations, maintaining the same 95% confidence level. Since BA(2) expenditures average nearly $3750 million per year, a .4% reduction in that account would correspond to $15 million annually.

In summary, it appears that there is some conservatism in the estimation of planned obligations relative to the expenditures actually realized for the BA (1) account. However, this conservatism is not present in the calculations of the BA (2) account. In fact this account is being maintained with a confidence of not overspending of slightly less than 95%. Thus, this preliminary analysis indicates that the conservatism of the one account is offset by the higher risk taken in the

1/ The confidence interval of 90% probability used above applies to both the upper and lower limits. If the distribution is symmetrical, the confidence level for exceeding only the upper limit would be 95%.

other. Taken together the two accounts are presently calculated with little conservatism and with a very low probability of overspending. Therefore, only a small reserve is needed to protect for overexpenditures. On the other hand, if a larger reserve is desired, it would be reasonable to estimate planned obligations relative to actual expenditures with a lower degree of confidence and place more dependence on the reserve for protection.

5. TIME SERIES ANALYSIS

The following sections contain a brief description of time series analysis, a description of the analysis applied to the BA(1) and BA(2) data, and a discussion of forecasting and reserves needed to cover the unpredictable fluctuations.

5.1 Introduction to Time Series Analysis

The objective of applying time series analysis to a time series is to reduce the amount of fluctuation observed in the series which cannot be predicted, i.e., we would like to make the differences between forecasted values and observed values of the series as small as possible. In the case of the BA (1) and BA (2) accounts the forecast of monthly actual expenditures are based upon past values of actual expenditures and monthly planned obligations. The mechanism which gives the forecasts is called a transfer function - the end product of times series analysis. A transfer function model relating a series $\{Y_t\}$ called the output series, where Y_t is the actual expenditures recorded in period t to a series $\{X_t\}$, called the input or controlling series has the general form of

$$Y_t = f_o + f_1 Y_{t-1} + f_2 Y_{t-2} + \ldots + f_p Y_{t-p} + g_o X_t + g_1 X_{t-1} + \ldots + g_q X_{t-q}$$

$$+ a_t + h_1 a_{t-1} + h_2 a_{t-2} + \ldots + h_{q'} a_{t-q'} .$$

Where $\{a_t\}$ is a normally distributed random variable with mean equal to zero and corresponding to the "noise" or fluctuations which cannot be predicted. In most cases p, q and q' will be no greater than 2 or 3. The basic reference 1/ used for this analysis provides a guide for finding the model or models which give the best fit to a set of observations from an output series and its controlling series. The criteria for the "best" model is one which minimizes the standard deviation of the random components - $\{a_t\}$

5.2 Analysis of the BA (1) and BA (2) Data

The basic data used in the analysis of the BA (1) account is shown in Table 5-1. The first column $\{X_t\}$ is a record of executed planned obligations for FY 74, 75 and 76. The plan for monthly obligations is revised several times during a budget cycle. We have assumed that the last unrevised value for a month was the executed control value for that period. (The months are numbered consecutively starting with July 1973.) The second column contains the re-

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1/ Box and Jenkins, Times Series Analysis: Forecasting and Control

TABLE 5.1

MONTHLY BA1 ACCOUNTS AND MODEL STATISTICS FOR FY 74, FY 75, FY 76

	Month t	Planned Obligations $\{X_t\}$	Actual Expenditures $\{Y_t\}$	3 Month Lead Forecast $Y_{t-3}(3)$	Error $[Y_t - Y_{t-3}(3)]$	Built-in Reserve	Prob. of Act. Exp. Exceeding Plan. Obl.
	1	109	107.1				
	2*	105	107.2				
	3	106	100.8				
	4	107	102.1				
	5	105	103.4	**			
	6	103	101.8	103.518	-1.718	- .518	.58
FY 74	7	107	105.9	104.646	1.254	2.354	.19
	8	107	105.6	105.883	- .233	1.167	.33
	9	108	105.5	105.458	.042	2.542	.17
	10	106	105.1	105.715	- .615	.285	.46
	11	107	105.6	105.358	.242	1.642	.27
	12	112	106.9	107.605	- .705	4.395	.05
	13	112	108.4	108.592	- .192	3.408	.10
	14	112	111.6	108.003	3.597	3.997	.07
	15	121	103.0	111.079	-8.079	9.921	.00
	16*	105	112.6	109.026	3.574	-4.026	.93
	17	106	105.7	103.765	1.935	2.235	.20
FY 75	18	107	105.6	108.566	-2.966	-1.566	.72
	19*	109	109.2	107.044	2.156	1.956	.23
	20	109	107.7	108.255	- .555	.745	.39
	21	109	109.0	108.068	.932	.932	.36
	22*	109	110.7	108.338	2.362	.662	.40
	23	111	109.1	109.026	.074	1.974	.23
	24	120	115.7	112.080	3.620	7.920	.00
	25	113	112.1	112.203	- .103	.797	.38
	26	112	110.3	108.985	1.315	3.015	.13
	27	124	118.0	114.179	3.821	9.821	.00
	28*	112	112.1	113.377	-1.277	-1.377	.70
	29	110	102.6	107.980	-5.380	2.020	.23
	30*	107	111.2	110.142	1.058	-3.142	.88
FY 76	31	111	109.6	109.473	.127	1.527	.28
	32	111	110.6	111.547	- .997	- .547	.58
	33	111	108.5	110.415	-1.915	.585	.41
	34*	109	114.5	110.593	3.907	-1.593	.72
	35	113	109.5	111.186	-1.636	1.814	.25
	36	122	114.0	115.198	-1.198	6.802	.01
					μ_a=.079 σ_a=2.62	μ_R=1.93	

First five columns are in millions of dollars.

* Months for which actual expenditures exceeded planned obligations.

** The first forecast in the BA1 account is for month six because data on actual expenditures for one month and an iterative calculation process must be used by the forecasting model (see section 5.4).

TABLE 5.2

MONTHLY BA2 ACCOUNTS AND MODEL STATISTICS FOR FY 74, FY 75, FY 76

	Month t	Planned Obligations $\{X_t\}$	Actual Expenditures $\{Y_t\}$	3 Month Lead Forecast $Y_{t-3}(3)$	Error $[Y_t-Y_{t-3}(3)]$	Built-in Reserve	Prob. of Act. Exp. Exceeding Plan. Obl.
FY 74	1	308	290.8				
	2	308	303.7				
	3	303	293.8	299.459	- 5.659	3.541	.31
	4	312	305.3	303.128	2.172	8.872	.11
	5*	311	312.9	302.310	10.590	8.690	.11
	6	310	299.2	305.682	- 6.482	4.318	.27
	7*	307	308.7	303.517	5.183	3.483	.31
	8	309	304.3	303.524	.776	5.476	.22
	9	310	303.0	303.167	- .167	6.833	.17
	10	308	302.7	303.293	- .593	4.707	.25
	11	309	305.2	303.892	1.308	5.108	.24
	12	318	311.1	307.926	3.174	10.074	.08
FY 75	13	314	301.8	308.252	- 6.452	5.748	.21
	14*	314	318.6	311.510	7.090	2.490	.36
	15	305	303.3	305.091	- 1.791	- .091	.51
	16	324	320.3	313.106	7.194	10.894	.06
	17	324	321.1	313.117	7.983	10.883	.06
	18*	324	331.4	321.720	9.680	2.280	.37
	19*	325	325.1	322.291	2.809	2.709	.35
	20	320	309.5	319.959	-10.459	.041	.50
	21	317	314.9	317.850	- 2.950	- .850	.55
	22*	316	322.8	314.500	8.300	1.500	.42
	23	316	309.8	312.991	- 3.191	3.009	.34
	24	321	298.6	315.189	-16.589	5.811	.21
FY 76	25	315	301.4	313.182	-11.782	1.818	.40
	26	314	310.6	313.699	- 3.099	.301	.48
	27*	313	324.4	310.322	14.078	2.678	.35
	28	326	313.6	316.460	- 2.860	9.540	.09
	29	322	316.8	316.730	.070	5.270	.23
	30*	310	320.7	315.560	5.140	- 5.560	.78
	31	323	308.6	318.027	- 9.427	4.973	.24
	32	322	310.6	314.904	- 4.304	7.096	.16
	33*	314	324.8	316.443	8.357	- 2.443	.63
	34*	306	310.3	310.205	.095	- 4.205	.72
	35	317	312.3	310.679	1.621	6.321	.19
	36	318	307.5	309.971	- 2.471	8.029	.13
					$\mu_a = .22$ $\sigma_a = 6.92$	$\mu_R = 4.098$	

First five columns are in millions of dollars.

* Months for which actual expenditures exceeded planned obligations.

corded actual expenditures $\{Y_t\}$ for those months. Table 5-2 contains similar data for BA (2).

Removal of linear trends from the data was the first step in the analysis. Figures 5.1 through 5.4 show plots of the data with fitted trend lines for each of the four series. The fitted trend lines have the following form:

<u>BA (1)</u>

Planned obligations:	$Y'_t = .238t + 105.8$
Actual expenditures:	$X'_t = .253t + 103.6$

<u>BA (2)</u>

Planned obligations:	$Y'_t = .298t + 309.3$
Actual obligations:	$X'_t = .404t + 303.1$

(In the discussions which follow all values will be in millions of dollars.) The coefficients of t in these equations are the average rates at which planned obligations and actual expenditures were increasing during the three year period. Removal of the trend from a series requires that the trend value for a period be subtracted from the actual value to obtain a transformed series with no trend and a mean of zero. For example:

The transformed series: $\{x_t\} = \{X_t - X'_t\} = \{X_t - .238t - 105.8\}$

is the transformed series for the BA (1) planned obligations data. The standard deviation of the transformed data for actual expenditures in the BA (1) account is \$3.06 million - a 24% decrease from \$4.03 million. The standard deviation of the transformed data for actual expenditures in the BA (2) account is \$8.24 million - an 11% decrease from the standard deviation of \$9.24 million about the mean.

The derivation of transfer function models which fit the transformed series is a lengthy and complicated process including a certain amount of trial and error which will not be described here. The interested reader may refer to Appendix D which describes the methods of Box and Jenkins for developing transfer function models and Appendix E which contains a user's guide to the computer programs needed to employ these methods.

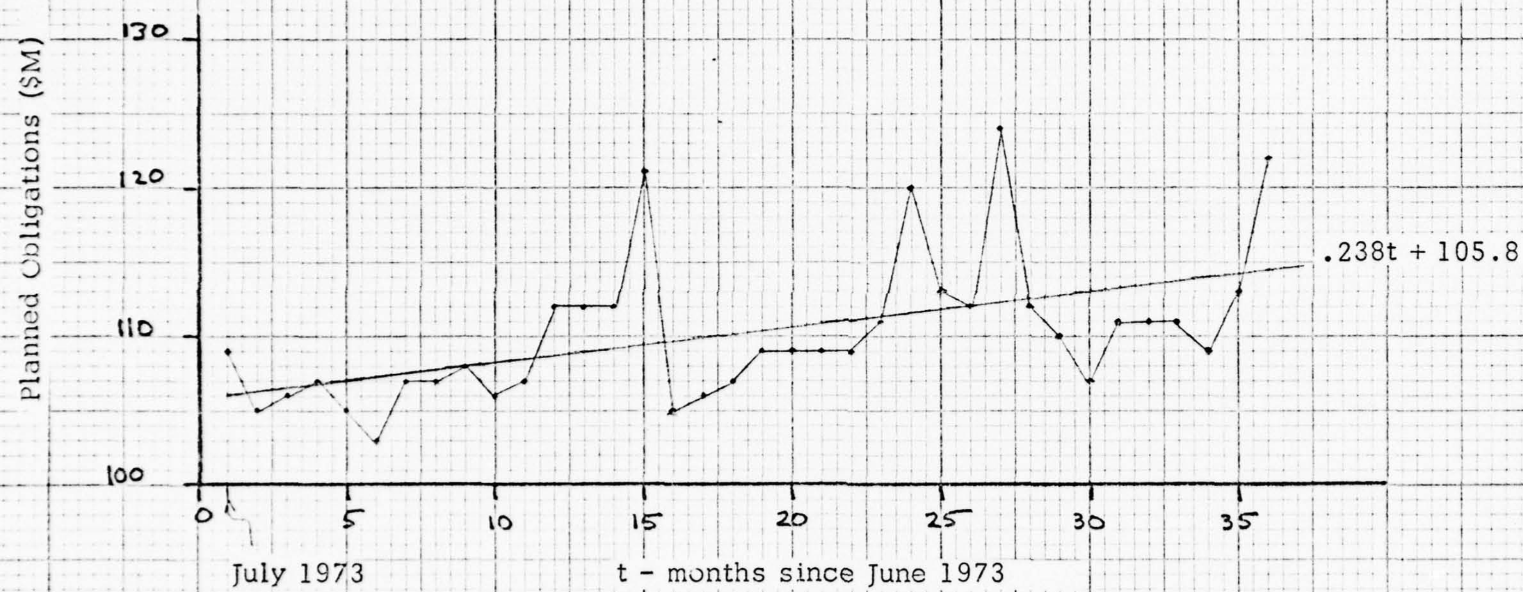


Figure 5.1

BA 1 Planned Obligations

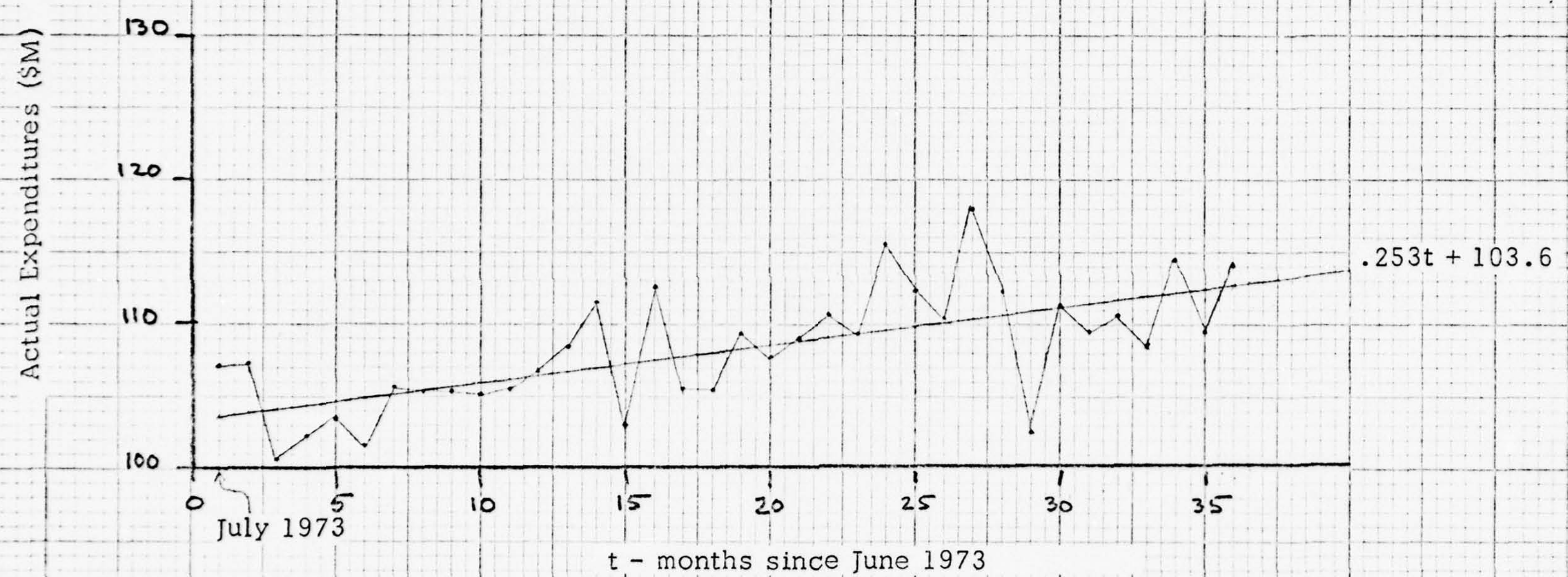


Figure 5.2
BA 1 Actual Expenditures

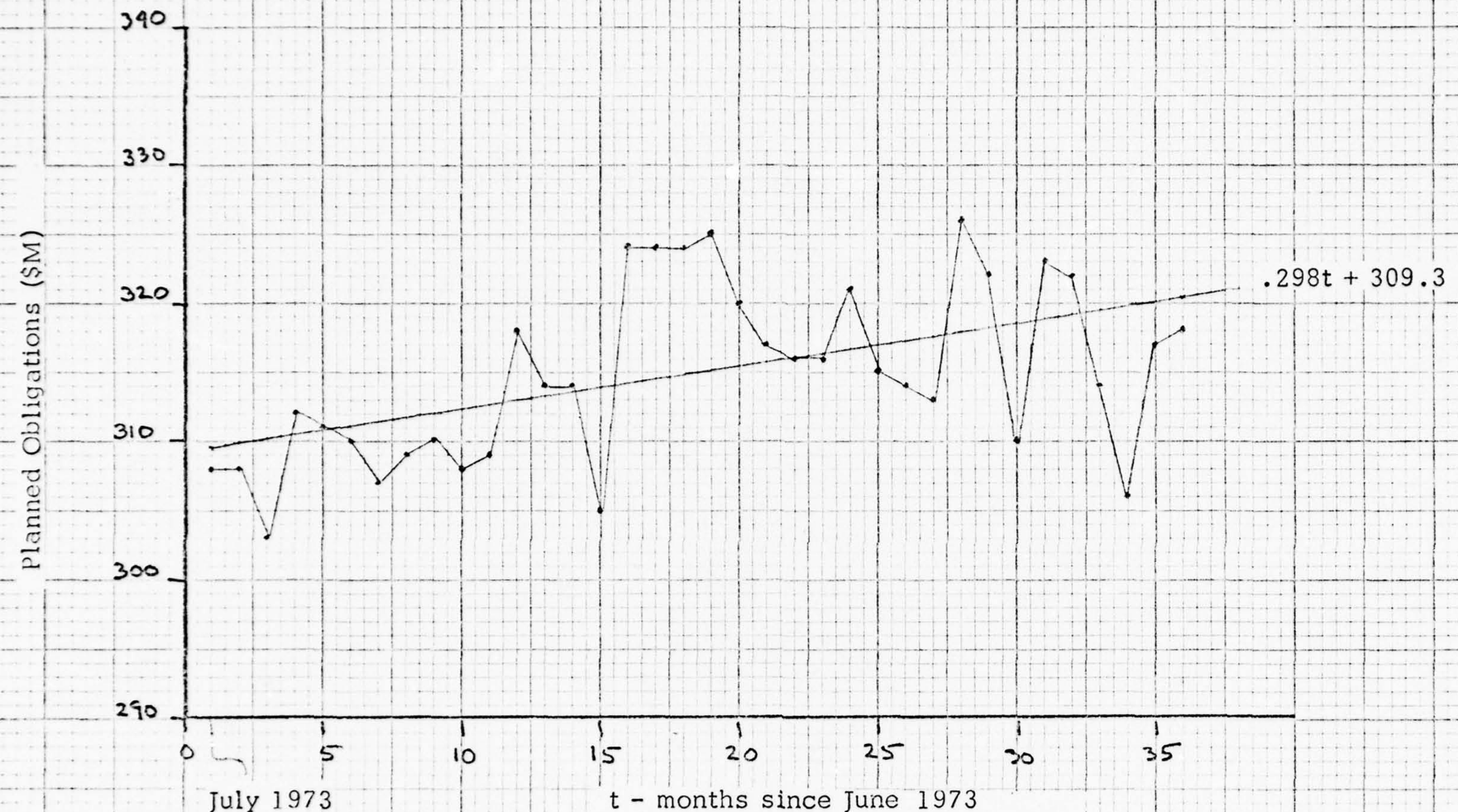


Figure 5.3

BA 2 Planned Obligations

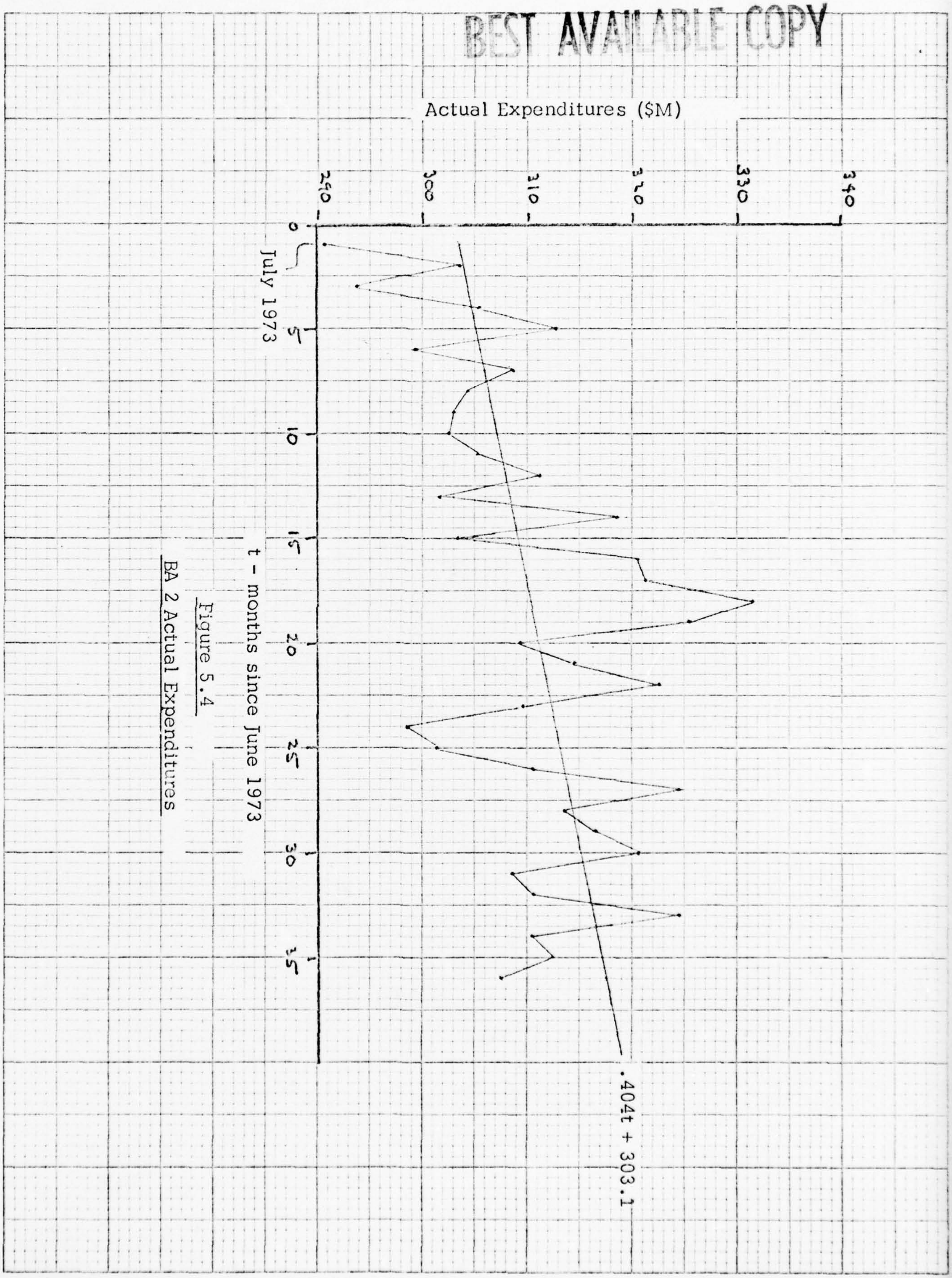


Figure 5.4

BA 2 Actual Expenditures

The basic method of Box and Jenkins is a two-staged approach. The first stage is to determine the number of each type of coefficient in (1) which are to be fitted and then apply a minimization technique to find the specific set of coefficients which gives the smallest set of residual values - the $\{a_t\}$ series. By applying these techniques to the transformed paired series for the BA (1) and BA (2) accounts the following two transfer function models for relating $\{y_t\}$ to $\{x_t\}$ were derived:

BA(1)

$$y_t = -.296y_{t-1} + .269x_t + .330x_{t-1} - .106x_{t-2} + .053x_{t-3} + a_t \qquad (6)$$

(σa = \$2.59 million)

BA(2)

$$y_t = .519x_t + .211x_{t-1} + .450x_{t-2} + a_t. \qquad (7)$$

(σa = \$7.14 million)

The models in terms of untransformed planned obligations $\{X_t\}$ and actual expenditures $\{Y_t\}$ have the form:

BA(1)

$$Y_t = -.296Y_{t-1} + .269X_t + .330X_{t-1} - .106X_{t-2} + .053X_{t-3} + .197t + 76.490 + a_t \qquad (8)$$

(σa = \$2.59 million)

BA(2)

$$Y_t = .519X_t + .211X_{t-1} + .450X_{t-2} + .052t - 61.543 + a_t \qquad (9)$$

(σa = \$7.14 million)

The response of the series of actual expenditures to changes in planned obligation are discussed in the next section.

5.3 Transfer Function Gain

A fundamental difference exists between the BA (1) and BA (2) accounts in terms of their response to changes in the input level of planned obligations. To illustrate the response of actual expenditures to planned obligations, let us assume that there is no noise in the system and that the planned obligations have not deviated from the trend lines given earlier prior to period 18 for both accounts. Under these conditions the actual expenditures would follow their trend lines also given earlier. Suppose the planned obligation figure for period 18 were increased by \$10 million followed by a return to the trend lines for all subsequent periods. The effect of this \$10 million impulse is shown in Figures 5.5 and 5.6 for the BA (1) and BA (2) accounts respectively.

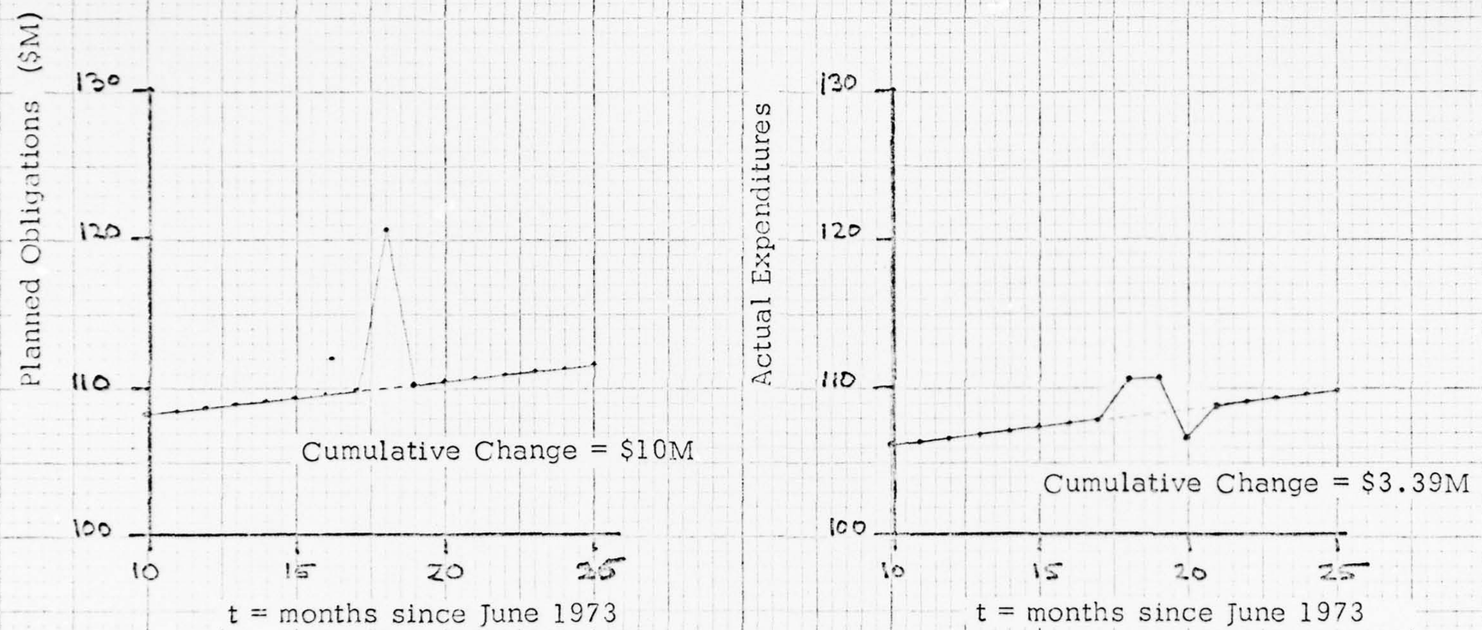


Figure 5.5

BA (1) - Impulse Response to $10 Million Input

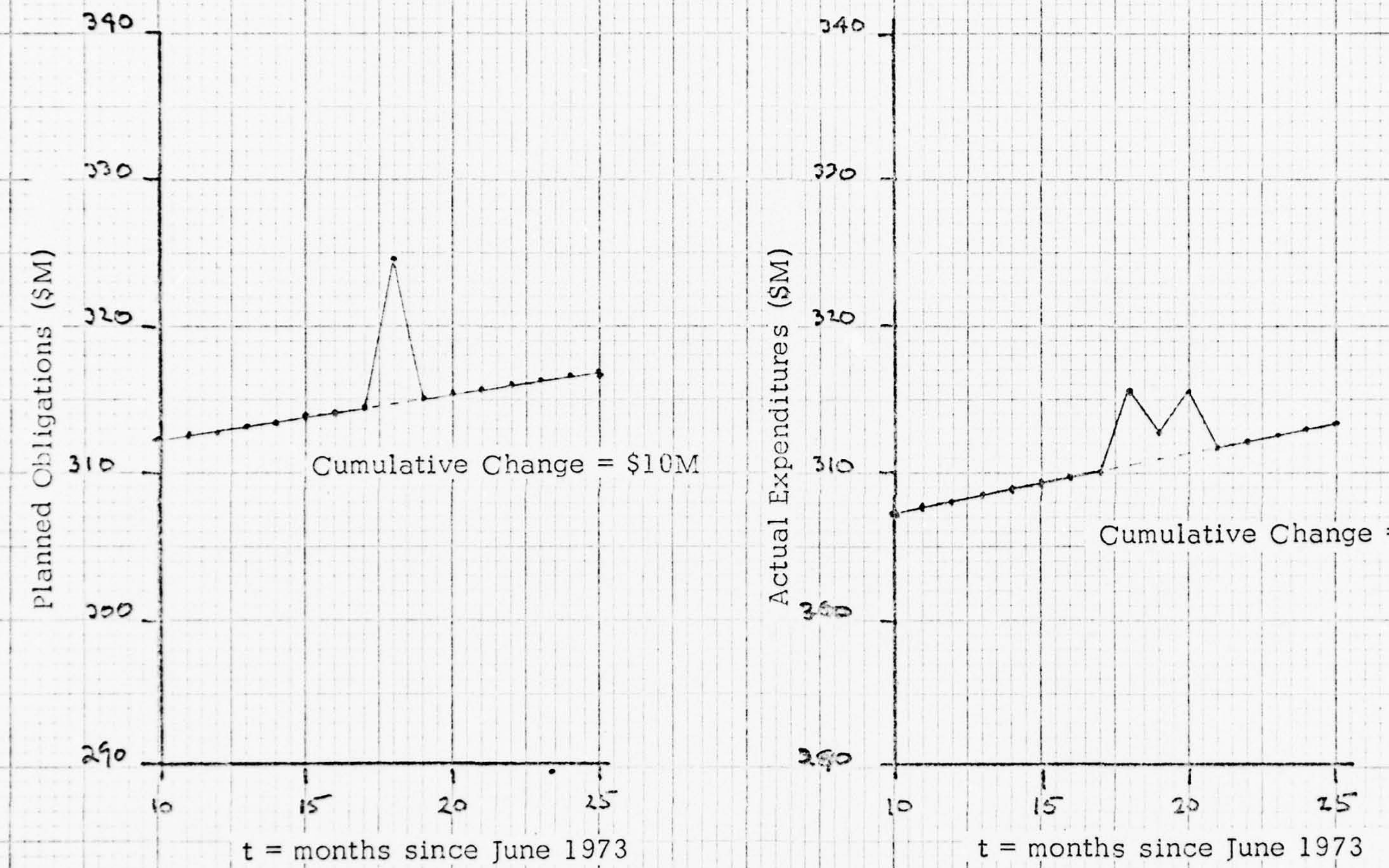


Figure 5.6

BA (2) - Impulse Response to $10 Million Input

In both cases the response to the impulse is spread over three periods the 18th, 19th and 20th. Also, in both cases the magnitude of the difference between these values for any period and the trend value is much less than the \$10 million impulse. However, the cumulative effort varies significantly. In the case of BA (1), the cumulative difference between the non-trend values and the trend values is only \$3.39 million. This corresponds to a "gain" factor in the BA (1) system of .339 (See Appendix D). For BA (2) the cumulative effect is \$11.80 million corresponding to a gain factor of 1.180.

These results show that the BA (1) system tends to shrink changes in planned obligations about its trend line while the BA (2) system tends to expand them. The consequences of these differences are made more explicit in the following sections on forecasting and built-in reserves.

5.4 Forecasting

Assuming the observed trends and underlying processes which relate planned obligations to actual expenditures remain unchanged, the model described by equations (8) and (9) can be used to forecast future actual expenditures given knowledge of the planned obligations to be executed. A forecast of the actual expenditures to be expected in month $t+k$ made from month t will be denoted by $\hat{Y}_t(k)$. Because of the past value of actual expenditures (Y_{t-1}) in equation (8), the forecasting technique for BA (1) and BA (2) will differ. Since the forecasting technique for BA(2) is simpler, it is described first.

BA (2) Forecasting

$$\hat{Y}_t(k) = .519X_{t+k} + .211X_{t+k-1} + .450X_{t+k-2} + .052(t+k) - 61.543. \qquad (10)$$

Equation (10) can be used to forecast the actual expenditures for the BA(2) account for any month as long as the planned obligations to be executed for that month and the preceding two months are known. The random component a_{t+k} is not shown since its expected value is zero. The random components will be brought back into the discussion when forecasting errors are addressed.

BA (1) Forecasting

$$\hat{Y}_t(k) = -.296\,\hat{Y}_t(k-1) + .269X_{t+k} + .330X_{t+k+1} - .106X_{t+k-2} + .053X_{t+k-3} + .197(t+k) + 76.490 \quad (11)$$

If k=1, then $\hat{Y}_t(k-1) = Y_t$; otherwise the forecast of $\hat{Y}_t(k)$ requires the forecast of the preceding month's actual expenditures. Therefore, forecasting for more than one month in advance requires an iterative procedure - first calculate $\hat{Y}_t(1)$, then $\hat{Y}_t(2)$, ..., then $\hat{Y}_t(k)$.

Forecasting Errors

The distributions of forecast errors for these models both have means equal to zero. The variances and corresponding standard deviations are given in Tables 5.3 and 5.4 for the BA (1) and BA (2) transfer function models. The cumulative error distribution is used to describe the distributions of errors from cumulative forecasts. Deviation of the distribution of forecasts made k periods ahead, V(k), and the distribution of cumulative forecast errors made k periods ahead, $\overline{V}(k)$, are given in Appendix D.

The third column of Tables 5.1 and 5.2 contains three month lead forecasts of actual expenditures. The fourth column contains the difference between the actual value and the forecast $(Y_t - \hat{Y}_{t-3}(3))$ called the forecast error.

5.5 Built-in Reserves

There are two methods used by BuPers to reserve funds as safeguards for overexpenditures. A reserve is set aside before planning is begun and an excess is built into the plans. This section considers the built-in reserves in evidence during FY's 74, 75 and 76 where the expected level of actual expenditures which would have been predicted by the models using a three month lead are compared with the planned obligations for these years. Total reserves needed for the future are also considered.

Monthly Built-In Reserves

A three-month lead period for forecasting actual expenditures for an executed plan of obligations is felt to be the shortest period for implementing a new plan. The fifth column in Tables 5.1 and 5.2 shows the difference be-

TABLE 5.3

BA(1) FORECAST AND CUMULATIVE FORECAST ERROR VARIANCES

AND STANDARD DEVIATIONS

Forecast Lead k	Forecast Error Variance $V(k)$	Forecast Error S.D. $\{V(k)\}^{\frac{1}{2}}$	Cumulative Forecast Error Variance $\overline{V}(k)$	Cumulative Forecast Error S.D. $\{\overline{V}(k)\}^{\frac{1}{2}}$
1	6.69	2.59	6.69	2.59
2	7.17	2.68	17.93	4.23
3	7.21	2.69	30.73	5.54
4	7.23	2.69	44.03	6.64
5	7.23	2.69	57.46	7.58
6	7.23	2.69	70.94	8.42
7	7.23	2.69	84.44	9.19
8	7.23	2.69	97.93	9.90
9	7.23	2.69	111.43	10.56
10	7.23	2.69	124.93	11.18
11	7.23	2.69	138.43	11.77
12	7.23	2.69	151.93	12.33

TABLE 5.4

BA(2)- FORECAST AND CUMULATIVE FORECAST ERROR VARIANCES AND STANDARD DEVIATIONS

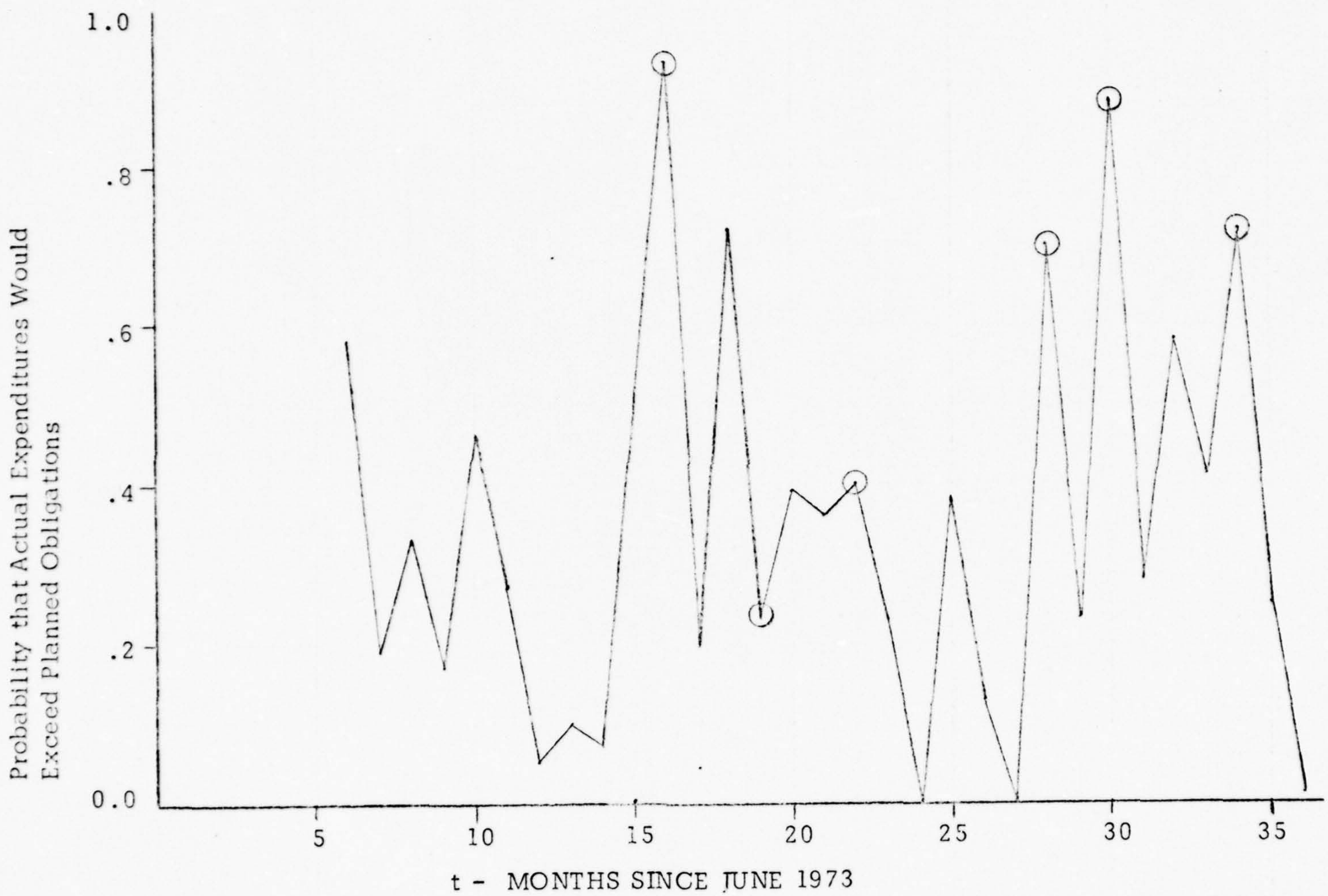
Forecast Lead k	Forecast Error Variance $V(k)$	Forecast Error S.D. $\{V(k)\}^{\frac{1}{2}}$	Cumulative Forecast Error Variance $\bar{V}(k)$	Cumulative Forecast Error S.D. $\{\bar{V}(k)\}^{\frac{1}{2}}$
1	51.05	7.14	51.05	7.14
2	51.05	7.14	102.10	10.10
3	51.05	7.14	153.15	12.38
4	51.05	7.14	204.20	14.29
5	51.05	7.14	255.25	15.98
6	51.05	7.14	306.30	17.50
7	51.05	7.14	357.35	18.90
8	51.05	7.14	408.40	20.21
9	51.05	7.14	459.45	21.43
10	51.05	7.14	510.50	22.59
11	51.05	7.14	561.55	23.70
12	51.05	7.14	612.60	24.75

tween the planned obligations for each month and a forecast of that month's actual expenditures which could have been made three months earlier. The average monthly built-in reserve for BA(1) is $1.93 million and for BA(2) it is $4.10 million. The sixth column of the previously mentioned tables give the probability that actual expenditures would exceed planned obligations for each month thus indicating the degree of protection offered by the monthly built-in reserve. The probabilities are calculated by dividing the monthly built-in reserve by the three month lead forecast error standard deviation, which makes it a standard normal deviate, and finding the probability that a standard normal variable would deviate from zero by at least that amount. Figures 5.7 and 5.8 are graphical plots for BA(1) and BA(2) of these probabilities with the values for months when actual expenditures did exceed planned obligations indicated. The average level of protection is approximately the same for both accounts (.33 for BA(1) and .31 for BA(2)). The wide variation of the probabilities for both accounts would indicate that the building in of a reserve is not done on a systematic basis.

Yearly Built-in Reserves

The approach for looking at yearly built-in reserves was modified somewhat to account for the fact that the plan for monthly obligations is changed periodically during the year. Instead of using executed plans, the last full year plan existing prior to the beginning of FY's 75 and 76 were used. For FY 75 this was PLAN E and for FY 76 it was PLAN F. FY 74 was not analyzed since the planned obligations executed in the latter half of FY 73 would be needed for the forecasts. The built-in reserve was calculated by using the plans for each year and the executed planned obligations from the preceeding year to forecast actual expenditures for each month of the year as if the plan were to be executed. The forecasts were summed and subtracted from the sum of the monthly planned obligation values in the plan to obtain the built-in reserve. The plans and forecasts are shown in Table 5.5 for BA (1) and Table 5.6 for BA (2). As indicated in Table 5.5, PLAN F for BA (1) in FY 76 actually had a built-in deficit.

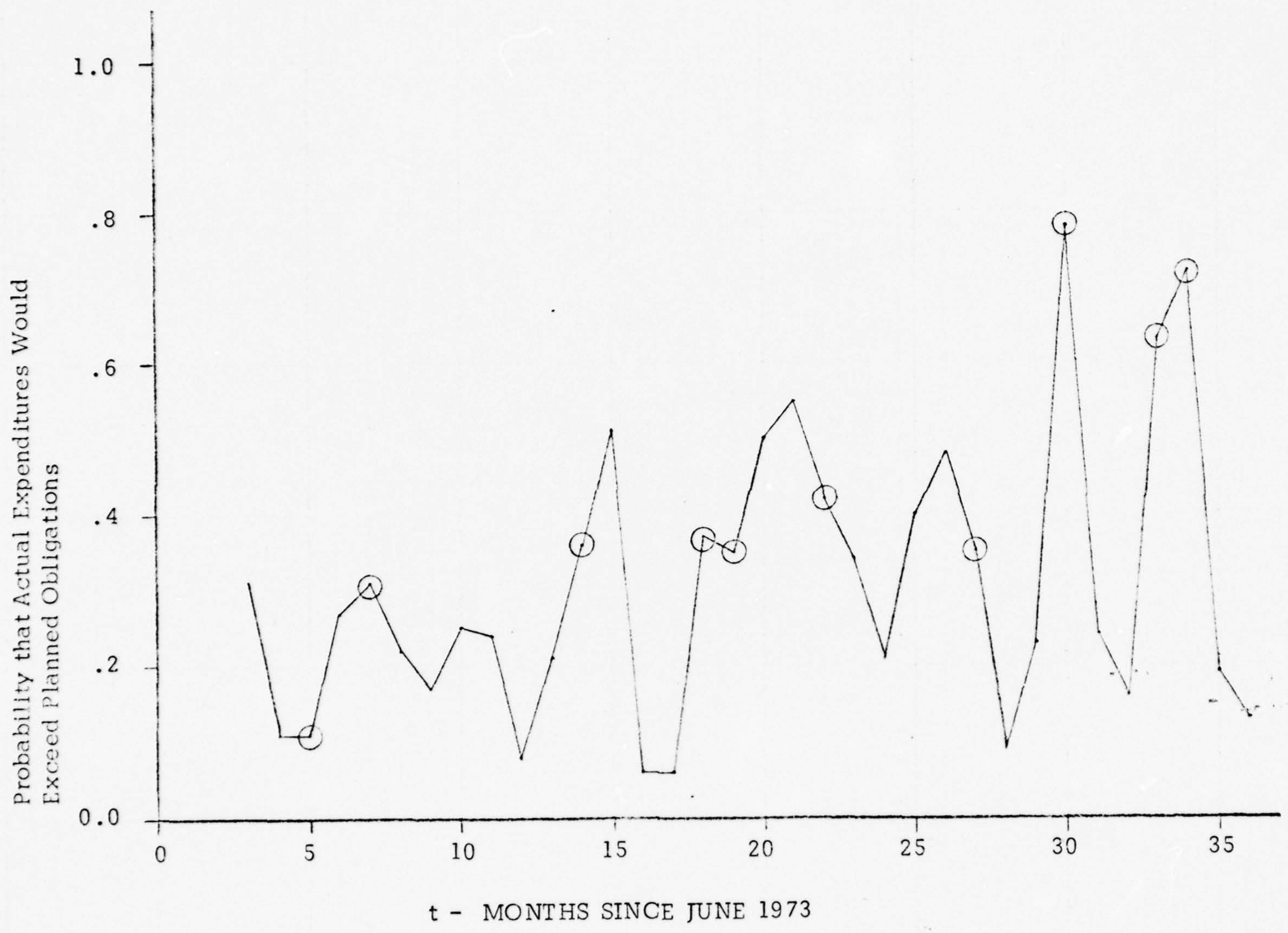
The explanation for the deficit comes from considering the gains of the transfer functions for BA (1) and BA (2). Figures 5.9 and 5.10 contain plots of PLAN E and PLAN F for both BA (1) and BA (2). Also shown on the graphs are the



NOTE: Circled points indicate months for which actual expenditures exceeded planned obligations.

Figure 5.7

BA1 - Probability that Actual Expenditures Would Exceed Planned Obligations Using Three Month Forecast



NOTE: Circled points indicate months for which actual expenditures exceeded planned obligations.

Figure 5.8

BA2 - Probability that Actual Expenditures Would Exceed Planned Obligations Using Three Month Forecast

TABLE 5.5

BA(1) - MODEL FORECASTS BY MONTH FOR FY 75 AND 76

	Month	Plan E Planned Obligations	Actual Expenditures Forecast From Month 12
(July 74)	13	112	108.773
	14	112	107.938
	15	121	111.068
	16	105	109.005
	17	106	103.848
FY 75	18	107	108.343
	19	107	106.585
	20	107	107.250
	21	108	107.572
	22	107	107.735
	23	109	107.986
	24	+ 126	+ 113.500
		1327	1299.602

Built-in Reserve = 1327 - 1299.602 = 27.40

S.D. of 12 month Cumulative Forecast = 12.33

Probability of Cum. Act. Exp. Exceeding $1327M under Plan E = .0131

	Month	Plan F Planned Obligations	Actual Expenditures Forecast From Month 24
(July 75)	25	113	111.176
	26	112	109.285
	27	124	114.159
	28	104	111.228
	29	104	104.368
FY 76	30	103	109.082
	31	106	107.301
	32	106	109.121
	33	106	108.408
	34	106	108.975
	35	107	109.273
	36	+ 119	+ 112.940
		1310	1315.316

Built-in Reserve = 1310 - 1315.316 = -5.32

S.D. of 12 month Cumulative Forecast = 12.33

Probability of Cum. Act. Exp. Exceeding $1310M under Plan F = .67

TABLE 5.6

BA(2) - MODEL FORECASTS BY MONTH FOR FY 75 AND 76

	Month	Plan E Planned Obligations	Actual Expenditures Forecast From Month 12
(July 74)	13	314	308.247
	14	314	311.505
	15	305	305.086
	16	324	313.100
	17	324	313.111
FY 75	18	324	321.713
	19	323	321.246
	20	322	320.568
	21	322	319.959
	22	320	318.523
	23	319	317.634
	24	+ 323	+ 318.651
		3834	3789.343

Built-in Reserve = 3834 - 3789.343 = 44.66
S.D. of 12 month Cumulative Forecast = 24.75
Probability of Cum. Act. Exp. Exceeding $3834M under Plan E = .0356

	Month	Plan E Planned Obligations	Actual Expenditures Forecast From Month 24
(July 75)	25	315	313.173
	26	314	313.690
	27	313	310.312
	28	311	308.665
	29	308	306.288
FY 76	30	305	303.250
	31	306	301.838
	32	305	300.232
	33	305	300.523
	34	304	299.606
	35	304	299.447
	36	+ 306	+ 300.087
		3696	3657.111

Built-in Reserve = 3696 - 3657.111 = 38.89
S.D. of 12 month Cumulative Forecast = 24.75
Probability of Cum. Act. Exp. Exceeding $3696M Under Plan F = .0581

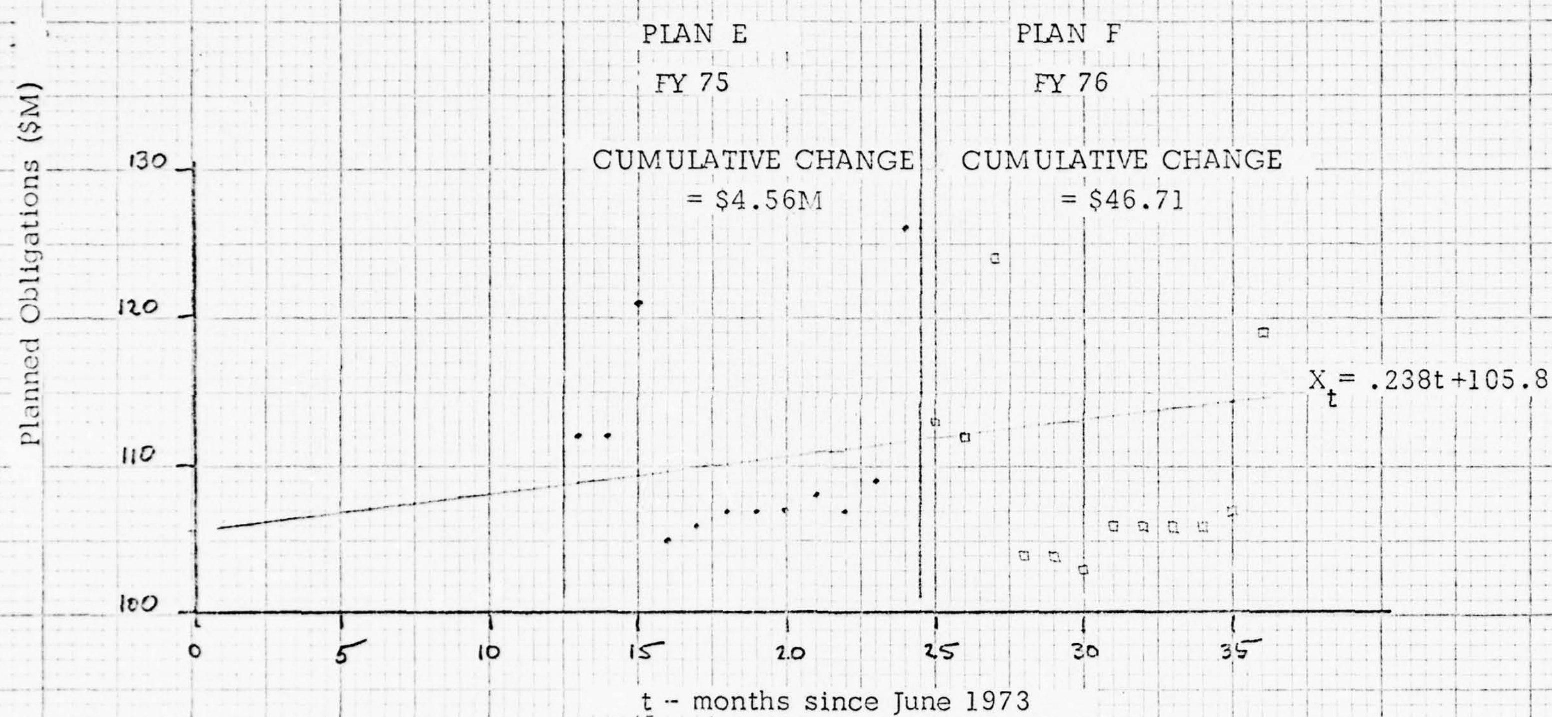


Figure 5.9
BA (1) - FY 75 PLAN E and FY 76 PLAN F Planned Obligations

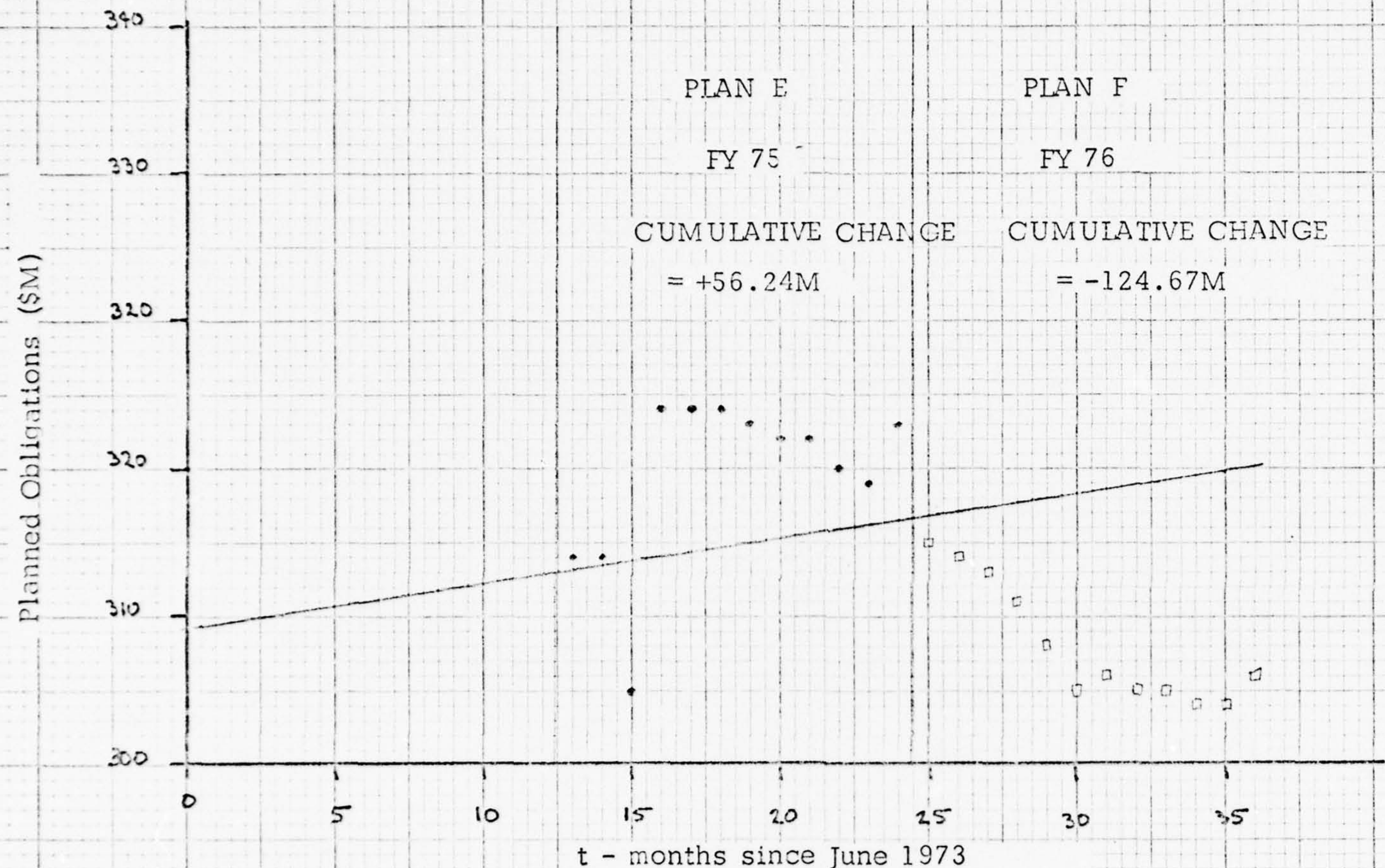


Figure 5.10

BA (2) - FY 75 PLAN E and FY 76 PLAN F Planned Obligations

trend lines for planned obligations for each account. As was discussed previously, the gain, g, of a transfer function is a rough measure of the cumulative affect of differences between the trend line and planned obligations on actual expenditures. Let ΔX_t be the difference between a planned obligation for period t and the trend value, X_t. Let Y_t be the trend value for actual expenditures, then the built-in reserve for FY 75 can be written as

$$\text{Built-in reserve} = \sum_{i=1}^{12} (X_{12+i} + \Delta X_{12+i}) - \sum_{i=1}^{12} Y_{12+i} - g \sum_{i=1}^{12} \Delta X_{12+i}$$

$$= \sum_{i=1}^{12} (X_{12+i} - Y_{12+i}) + (1-g) \sum_{i=1}^{12} \Delta X_{12+i}$$

For BA (1) this formula becomes:

$$\text{Built-in reserve} = \sum_{i=1}^{12} \left[.238(13+i) + 105.8 - .253(13+i) - 103.6\right]$$

$$+ (1-.339)\ (4.56)$$

$$= (12\times13+78)\ (.238 -.253) + 12\ (105.8 - 103.6) + .661(4.56)$$

$$= 25.90$$

Similar calculations using the gain relationship were done for BA (1) in FY 76 and both FY plans for BA (2). The results of these calculations are shown in Table 5.7 along with the built-in reserves as calculated using the forecasts.

Agreement between the gain calculations and the forecasting values supports the conclusion that gains of the transfer functions are a key to understanding long term effects of plans on actual expenditures. It should also be noted that BA (1) plans which go below the trend line are much more likely to have built in deficits than BA (2) plans which go below the trend line. This is because the BA (1) actual expenditures move away from the trend line at only .339 times the rate of the planned obligations. The low gain makes it possible for the cumulative planned obligations to dip below cumulative actual expenditures. The next two paragraphs discuss the level of protection afforded by these plans had they been executed.

TABLE 5.7

COMPARISON OF BUILT-IN RESERVE ESTIMATES FROM

TABLES 5.5 AND 5.6 AND THE GAIN CALCULATION

	BA (1)	BA (2)
Tables 5.5 and 5.6	27.40	44.66
FY 75 Built in Reserve Gain Calculation	25.90	47.74
Tables 5.5 and 5.6	-5.32	38.89
FY 76 Built-in Reserve Gain Calculation	-10.15	56.77

The standard deviation of a 12 month cumulative forecast as listed in Table 5.5 for BA (1) is $12.33 million. Had PLAN E been executed in FY 75 for BA (1) the built-in reserve of $27.9 million would have assured that cumulative expenditures would have exceeded cumulative planned obligations with a probability of only .0131. On the other hand, the built-in deficit in PLAN F for FY 76 resulted in a probability of .67 that cumulative actual expenditures would exceed cumulative planned obligations had the plan been executed.

Both plans shown for BA(2) in Table 5.6 contained substantial built-in reserves. The built-in reserve of $44.7 million in PLAN E resulted in a probability of only .04 that cumulative expenditures would exceed cumulative planned obligations. With the built-in reserve of $38.9 million for PLAN F in FY 76 there was only a .06 probability that cumulative expenditures would exceed cumulative planned obligations.

5.6 Future Reserves

The total reserves needed to cover fluctuations in cumulative actual expenditures for a year is not necessarily a function of 12 month cumulative forecast error. If any discrepancies between cumulative expenditures and cumulative planned obligations can be incorporated into a new plan to be executed beginning with the last few months of the fiscal year, then the total reserves needed for a certain confidence level of protection will be a function of a much shorter cumulative forecast error standard deviation.

Table 5.8 shows the total reserve necessary to afford the level of protection shown and a corresponding necessary lead time for both accounts. For example, the value of 9.1 under 95% and across from 3 in the table for BA 1 indicates that a total reserve of $9.1 million would be enough to assure that 95% of the time this reserve would cover the cumulative error between forecasted actual expenditures and actual expenditures for the last three months of the year. Assuming that any discrepancy between cumulative planned obligations and actual expenditures for the first nine months can be incorporated into the plan for the last three months, then $9.1 million would be the only reserve needed.

TABLE 5.8

YEARLY RESERVES ($M) WHICH ARE NEEDED TO COVER EXCESS OF CUMULATIVE ACTUAL EXPENDITURES OVER FORECASTS FOR LEAD TIMES FROM 3 - 6 MOS.

Lead Time of Forecast	(BA 1) 80%	Confidence Levels 90%	95%	99%
3	4.7	7.1	9.1	12.9
4	5.6	8.5	10.9	15.4
5	6.4	9.7	12.5	17.6
6	7.1	10.8	13.9	19.6
	(BA 2)			
3	10.4	15.9	20.4	28.8
4	12.0	18.3	23.5	33.3
5	13.5	20.5	26.3	37.2
6	14.7	22.4	28.8	40.72

The reserves shown in Table 5.8 were calculated assuming that the linear trends in the planned obligations and actual obligations would remain unchanged as well as the underlying process. If these assumptions are no longer true, then the confidence levels shown may no longer be valid.

5.7 Summary of Results of the Time Series Analysis

The time series analysis of three years of monthly data for the officer BA(1) and enlisted BA(2) accounts has yielded the following results:

- The application of time series analysis to the monthly planned obligations and actual expenditure data for the officer BA(1) and enlisted BA(2) accounts has generated models which reduce significantly the standard deviation of the unpredictable fluctuations in actual expenditures for both accounts. The model for the BA 1 account has reduced the standard deviation of the actual expenditures about their mean from $4.03 million to an unpredictable variation with a standard deviation of $2.59 million -- a 36% decrease. The variation in the BA 2 account was reduced from a standard deviation of $9.24 million to a standard deviation of $4.14 million -- a 23% decrease.

- There are two methods of reserving funds used by BuPers as safeguards against overspending. CHNAVPERS first removes a contingency or reserve before planned obligations are calculated. Pers 2 and Pers 3 may have a built-in reserve in the planned obligations. Employment of transfer function models as a tool for control potentially will allow BuPers to hold the total amount of reserves obtained from both methods to between $9.1 million and $13.9 million for the BA(1) account with a 95% expectation that the total reserve will be sufficient. A reserve of between $20.4 million and $28.8 million will suffice for the enlisted BA(2) account for the same level of coverage. The minimum reserves correspond to a reasonable lead time of three months to execute a new monthly plan of planned obligations, while the maximum reserves correspond to a conservative estimate of six months.

- A fundamental difference exists between the BA (1) and BA (2) systems with respect to their response to differences between planned obligations and the trend for planned obligations. The BA (1) account tends to significantly shrink the differences in terms of actual expenditures while the BA (2) system tends to slightly expand the response. Due to the significant shrinkage in the BA (1) system, it is prone to large built-in reserves when planned obligations are above the trends line for planned obligations and small deficits when it is below.

- Use of the models to reduce the variance of actual expenditures by generating forecasts indicates that each account contains a built-in reserve in planned obligations. This reserve amounts to an average of $1.93 million per month difference between planned obligations and forecasted expenditures in the BA (1) account and an average of $4.10 million per month in the BA (2) account.

- The same logic applied to cumulative planned obligations as contained in PLAN E, the final plan of planned obligations to begin FY 75, and the cumulative forecast for BA (1) indicates that the plan had a built-in reserve of $27.40 million corresponding to a probability of .0016 that cumulative expenditures would have exceeded the cumulative planned obligations had the plan been executed.

- PLAN F, the final plan to begin FY 76 had a built-in deficit of $5.32 million for BA (1) with a probability of .72 that had the plan been executed, cumulative expenditures would have exceeded cumulative planned obligations.

- PLAN E for BA (2) in FY 75 had a built-in reserve of $44.7 million with a corresponding probability of .04 and PLAN F for BA (2) in FY 76 had a built-in reserve of $38.9 million corresponding to a probability of .06 that cumulative expenditures would not have exceeded the cumulative planned obligations of the plan.

6. CONCLUSIONS AND RECOMMENDATIONS

The analysis of financial data of the BA (1) and BA (2) accounts of the past three fiscal years shows that BuPers has exerted close control in keeping a proper relationship between actual expenditures and planned obligations. BuPers has maintained a reasonable margin of safety in those two accounts ensuring that actual expenditures do not exceed planned obligations on a cumulative basis during the fiscal years examined. Still further refinements and improvements in the methods and procedures are possible. This study provides a look at time series analysis as a potential aid to BuPers for explaining, controlling, and providing for variations between actual expenditures and planned obligations as they are now determined. The authors believe that their analysis supports the following:

1. The application of time series analysis to the three-year financial data has resulted in a model which has the potential to be used in forecasting expenditures, i.e., planned expenditures, for BA (1) and BA (2) from planned obligations as established in the plan at the beginning of the fiscal year. Furthermore, the analysis shows that actual expenditures in the BA (1) account for any year will not exceed the forecast expenditures by more than 9.1 to 13.9 million with a 95% level of confidence. These figures represent the margin of safety needed in the last three or six months of the year, respectively, when it is assumed no further adjustments may be made to the account to increase or decrease expenditures. Therefore, a reserve of between 9.1 to 13.9 million can be maintained to assure that the BA (1) account is not overspent. Part of this reserve, if not all of it, may already be maintained in the difference between cumulative forecasted expenditures from the model and total planned obligations. When this excess does not account for the total 9.1 to 13.9 million reserve needed, a small contingency may be left unobligated initially as an added reserve, a practice which is presently used by BuPers. However, should the difference between cumulative forecasted expenditures and planned obligations be larger than what is needed, a new plan of obligations can be used in the model to obtain a new

forecast and an acceptable difference. Similarly for the BA (2) account, the margin of safety to be added to the forecasted expenditures obtained from the model is between 20.4 and 28.8 million. An important caveat applies; these margins of safety are realistic only if time series analysis is initiated within BuPers and continually updated as changes in policies and procedures might occur. The model and its results hold only as long as the planned obligations and actual expenditures are consistent with the trend line observed from the three years of data. Changes in policy and procedures may cause a divergence from this norm. Also, within approximately six months of a given fiscal year, the data on actual expenditures is sufficient to show whether or not divergence from the trend line is occurring. If divergence is apparent, the trend line may need to be reevaluated and the forecasted results of the model examined further. Appendices to this report provide a discussion of Box-Jenkins analysis and users guide to the computer program developed by Ketron.

2. The discussion in Section 3 on operation procedures for BuPers and, in particular, Pers 3, represents an understanding that is essential for appropriate utilization of the models for time series analysis of BuPers data. The authors recommend that these procedures be updated and expanded to include in detail other divisions within BuPers, notably Pers 2 and Pers 223, that participate extensively in the MPN budget program. There are a number of reasons for this recommendation. As stated before, the present programs offer a model that approximates the data, i.e., planned obligations and actual expenditures, as they are now determined. Should procedures for the determination of this data change, then the model must be changed in keeping with alterations made in procedures or processes. Procedural documentation then becomes a guideline for adjusting the model as well as a good historical record of organizational changes and sequential adaptations needed in the model. Updated records on processes, procedures and interactions between divisions also offer material for an efficient training program.

3. The authors suggest that an examination be made of JUMPS, the data it receives and supplies, and how total usage of JUMPS information may alter

and enhance present operating procedures within BuPers. An examination of the effect JUMPS input will have on the model presented in this report would necessarily follow. Further study should be given to additional use of computers for functions that are now performed manually. This may involve a look at the interdependency of divisions and possible redundancy of calculations being performed.

APPENDIX A

COMPARISON OF YEARLY APPROPRIATIONS
AND EXPENDITURES FOR BA(1) AND BA(2),
1961 - 1975

TABLE A-1

OFFICER PAY AND ALLOWANCES
(In Millions of Dollars)

Fiscal Year	Annual Program	Actual	Difference	Percent
1961	599.0	592.7	6.1	1.0
62	622.0	623.0	-1.0	-.16
63	634.2	634.6	-0.4	-.06
64	712.6	711.8	0.8	.11
65	768.0	767.8	0.2	.03
66	818.6	817.8	0.8	.10
67	887.5	879.4	8.1	0.9
68	932.0	930.5	1.5	.16
69	1,023.8	1,025.7	-1.9	-.19
70	1,127.8	1,126.0	1.8	.16
71	1,123.2	1,127.5	-4.3	-.38
72	1,173.8	1,197.1	-23.3	-2.0
73	1,262.0	1,240.0	22.0	1.7
74	1,278.7	1,253.1	25.6	2.0
75	1,318.2	1,298.2	20.0	1.5

Mean = .00331
Variance = .00009
Third moment = 2.3×10^{-7}
Fourth moment = 2.9×10^{-8}
Coefficient of
skewness = -0.26
Coefficient of
kurtosis = 3.41262

TABLE A-2

ENLISTED PAY AND ALLOWANCES
(In Millions of Dollars)

Fiscal Year	Annual Program	Actual	Difference	Percent
1961	1,688.1	1,663.7	24.4	1.4
62	1,766.7	1,746.2	20.5	1.2
63	1,784.7	1,760.9	23.8	1.3
64	1,862.8	1,850.8	12.0	0.6
65	1,947.7	1,946.9	0.8	0
66	1,156.2	1,157.9	-1.7	-0.1
67	2,496.1	2,447.4	48.7	2.0
68	2,645.7	2,634.9	10.8	0.4
69	2,841.4	2,842.2	-0.8	0
70	3,137.3	3,137.0	0.3	0
71	3,029.5	3,028.0	1.5	0
72	3,351.3	3,361.8	-10.5	-0.3
73	3,657.3	3,620.5	36.8	1.0
74	3,662.9	3,633.1	29.8	0.8
75	3,802.2	3,768.0	34.2	0.9

Mean = .00623
Variance = .00004
Third moment = 9.6×10^{-8}
Fourth moment = 3.7×10^{-9}
Coefficient of
skewness = .3453
Coefficient of
kurtosis = 2.02789

APPENDIX B

ORGANIZATIONAL FLOW CHARTS

APPENDIX B

ORGANIZATIONAL FLOW CHARTS

This appendix contains the organizational flow charts detailing the processes involved in MPN budget development and management as discussed in Section 3 entitled, "Organizational Processes," There are five flow charts presented in the following order:

- POM Development
- MPN Budget Preparation
- Management of the MPN Account
- Budget Execution
- Zeroing Out

The first four of the above flow diagrams outline those portions of Section 3 with corresponding subtitles. "Zeroing Out" is discussed in the section under the subcategory of "Budget Execution."

POM Development

In January the FYDP - Five Year Defense Program has been submitted to Congress.
This is the base for the development of the next POM. CNO begins the process by developing total picture estimates for the POM.

The previous year's budget developed by Pers 2 & Pers 3 affects these estimates.

MPN PLANNING COORDINATION & EXECUTION BR (223) develops new estimates for its own budgetary concerns to be included in the new POM. These include manpower estimates from Pers 2 and budget rates from Pers 3.

Other POM inputs from the Navy are also submitted to CNO/NAVCOMP.

Estimates go to the CNO/NAVY COMPTROLLER.

CNO/NAVCOMP make cuts and/or changes in estimates.

Estimates go to SEC NAV.

SECNAV makes budgetary changes or cuts.

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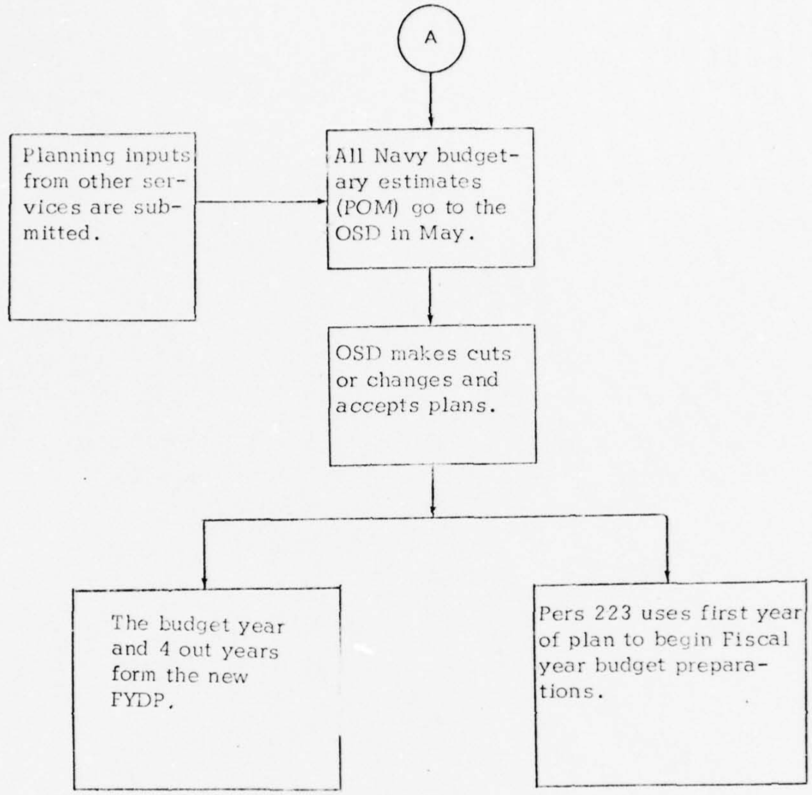
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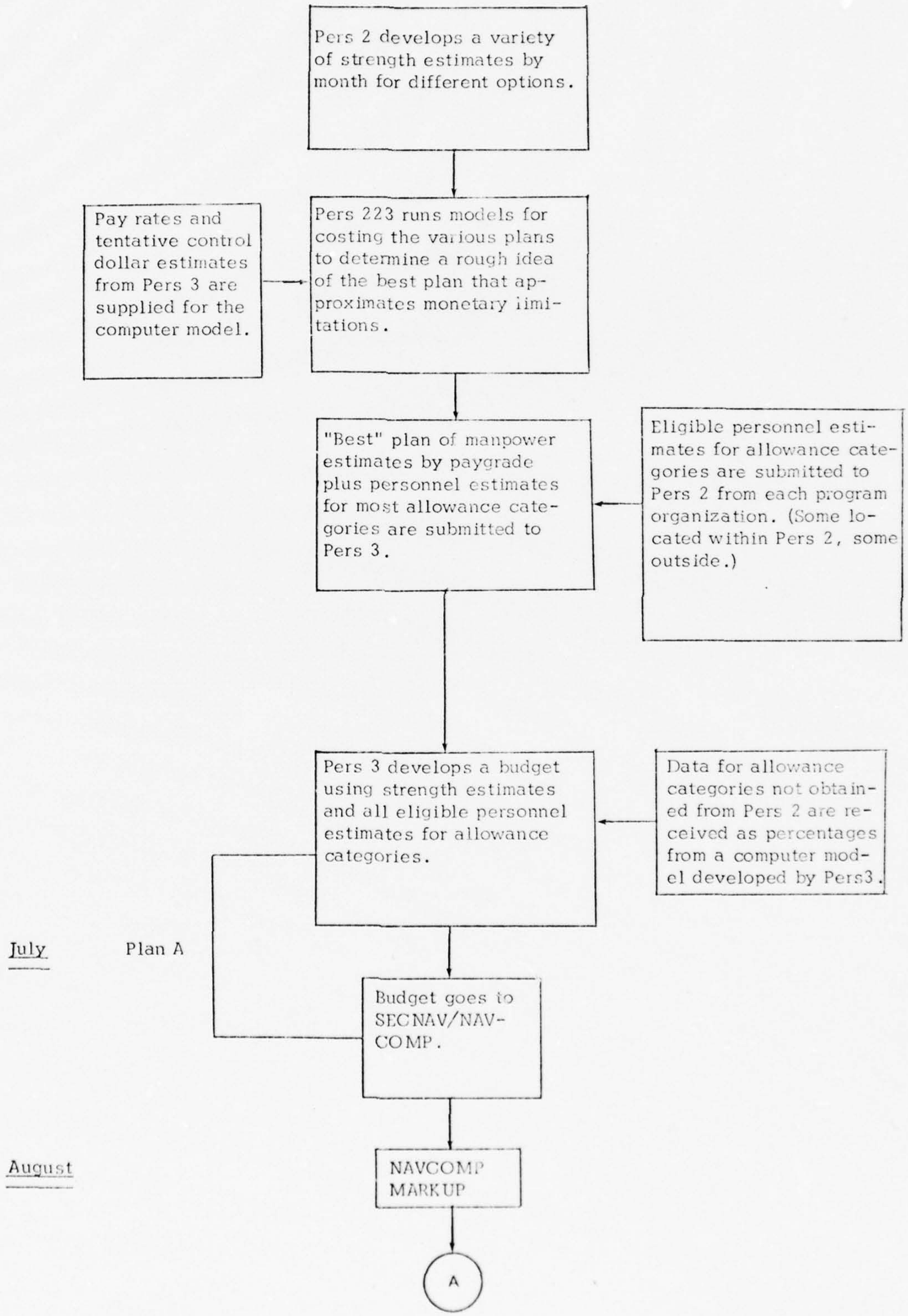
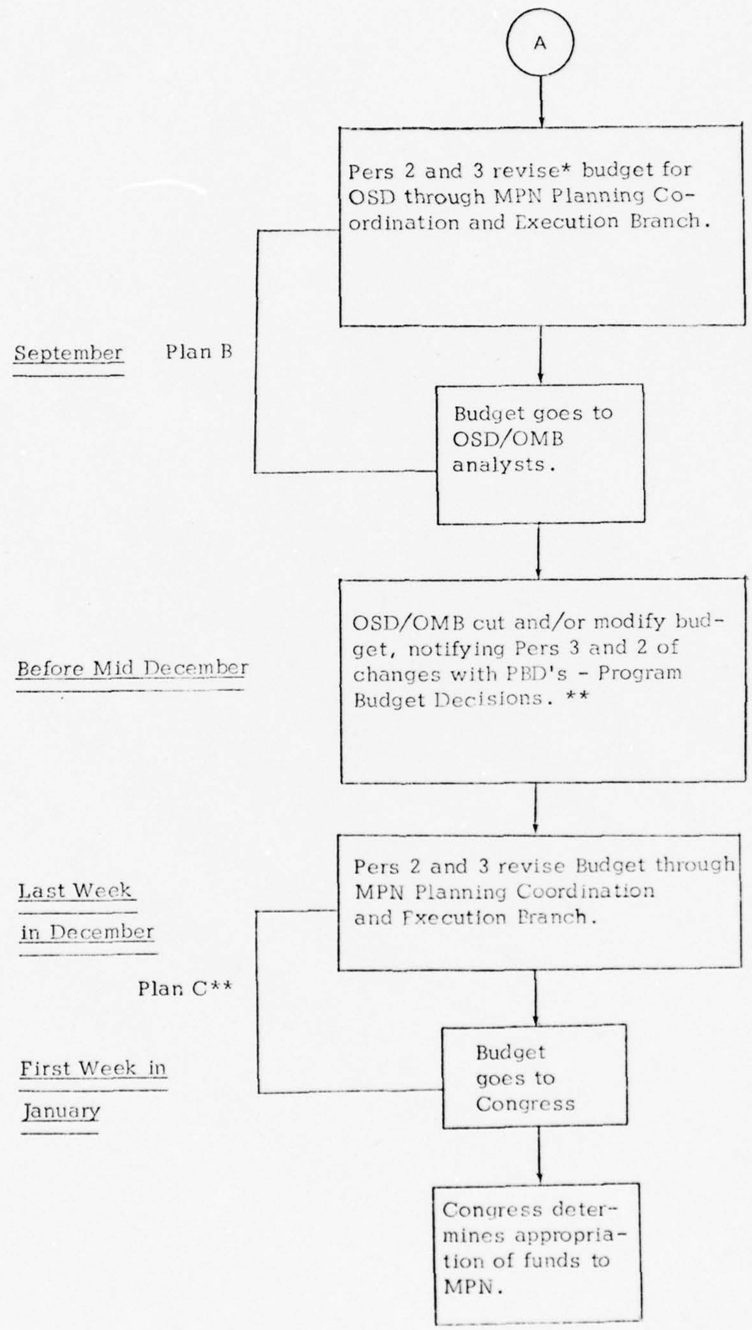
Planning inputs from other services are submitted.
All Navy budgetary estimates (POM) go to the OSD in May.
OSD makes cuts or changes and accepts plans.
The budget year and 4 out years form the new FYDP.
Pers 223 uses first year of plan to begin Fiscal year budget preparations.

MPN Budget Preparation





* CHNAVPER/OP-01 may appeal markup or PBD's with a reclama but this has become rare and is rarely successful.

** Other "plans" of the budget may arise from year to year depending on the participation of other reviewing organizations during the budget formulation. These three plans however, whatever their position in the reviewing order, are always developed.

Management of the MPN Account

Appropriation received from Congress

CHNAVPERS prepares 1105 - a request for the appropriated money in quarterly amounts.

Form 1105 is supported by a detailed Financial Plan which is a monthly phasing plan by subactivity. This Financial Plan may be submitted before or after the 1105. Revision of the plan after appropriation has occurred is sometimes necessary.

1105 sent to NAVCOMP

1105 sent to OSD/COMP

1105 sent to OMB. OMB allocates the money in the quarterly amounts requested or OMB withholds a specific amount from the fourth quarter allocation request.

CHNAVPERS receives the allocation by quarter and determines a manpower and monetary ceiling for internal planning, allowing for unforeseen requirements.

Pers 2 develops an operating plan of manpower * estimates within the limits and designs a phasing of the operating plan by month. This phasing expresses total manpower estimates by paygrades.

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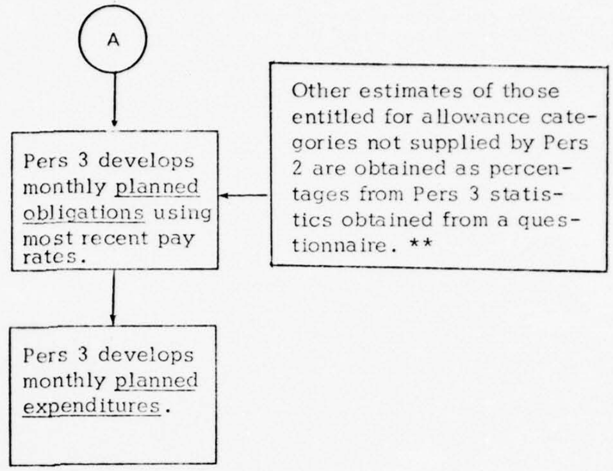

* If the operating plan is developed before appropriations are released, then this plan attempts to take into account expected cuts to the budget made by Congress.

** These statistics will no longer be gathered by Pers 3 when Pers 31 uses JUMPS - Joint Uniform Military Pay System - for statistical data.

Budget Execution

Three Month Time Frame	Obligations	Expenditures
Month A-1		
End of Month:	End of month strengths for Month A-2 are received.	
Month A		
Middle of Month:	Actual Obligations for Month A-1 are calculated, using: 1. Determination of Final Obligation for A-2, 2. Advanced Obligations for A-2, 3. Calculation of Advanced Obligation for A-1,	Expenditure report for Month A-1 are received.

$$\text{Adv. Obl. (A-1)} = \frac{\text{Final Obl. (A-2)} + \text{Planned Obl. (A-1)}}{2}$$

End of Month:	End strengths for Month A-1 are received.	
Month A+1		
Middle of Month:	Actual Obligations for Month A are calculated, using: 1. Determination of Final Obligation for A-1,	Expenditure reports for Month A are received. Actual expenditures written on ledger for A are adjusted by: 1. delayed reports of previous months, 2. corrections to previous reports.

$$\text{Final Obl. (A-1)} = \frac{\text{Actual End Strength (A-2)} + \text{Actual End Strength (A-1)}}{2}$$

x pay factors

2. Advanced Obligation of Month A-1,
3. Calculation of Advanced Obligation for Month A.

$$\text{Actual Obl. (A)} = \text{Advanced Obl. (A)} + (\text{Final Obl. (A-1)} - \text{Advanced Obl. (A-1)})$$

Zeroing Out

Actual Obligations which have been calculated are substituted for the Planned Obligations approximately every three months.

↓

Pers 2 revises its manpower estimates for the remaining months.

↓

Pers 3 revises its Planned Obligations for the remaining months.

APPENDIX C

FISCAL YEAR ANALYSIS

APPENDIX C

FISCAL YEAR ANALYSIS

Introduction

This appendix supports the material given in the section of the report, entitled, "Analysis of Data on a Fiscal Year Basis."
The derivation of the probabilities and conclusions discussed in that section are presented here in detail. The raw data used in the calculation of the sample statistics then follow.

Probability Derivation

A $(1 - \alpha)$ confidence interval for the mean, μ, of a normal population can be determined from the mean, $\bar{T}$, and standard deviation, S_T, of a random sample of the population. This is possible because the mean of a random sample of size n drawn from a normal population has a t distribution with n-1 degrees of freedom. Thus, it follows that

$$\bar{T} - t_{\alpha/2}^{(n-1)} \left[\frac{S_T}{\sqrt{n}} \right] \leq \mu \leq \bar{T} + t_{\alpha/2}^{(n-1)} \left[\frac{S_T}{\sqrt{n}} \right]$$

Given our sample of size three, a confidence interval of .90 is

$$\bar{T} - t_{.05}^{(2)} \left[\frac{S_T}{\sqrt{3}} \right] \leq \mu \leq \bar{T} + t_{.05}^{(2)} \left[\frac{S_T}{\sqrt{3}}, \right]$$

and

$$P \left[\mu \leq \bar{T} + t_{.05}^{(n-1)} \frac{S_T}{\sqrt{n}} \right] = .95$$

expresses the probability that the mean will be less than or equal to the upper bound. However we are not interested in the mean of the population, per se, but in a future value, x_f, of that population. We wish to determine the following probability:

$$P\left[x_f \leq \bar{T} + t_{.05}^{(n-1)}\left(\frac{S_T}{\sqrt{n}}\right)\right]$$

This is the probability that a future value will be less than or equal to the upper bound of the 90% confidence interval for μ. Calculation of this probability is as follows:

$$\text{Let} \qquad P\left[x_f \leq \bar{T} + t_{.05}^{(n-1)}\left(\frac{S_T}{\sqrt{n}}\right)\right] = P\left[X_f\right]$$

$$\text{Then} \qquad P\left[X_f\right] = \left[\frac{x_f - \mu}{\sigma} \leq \frac{\bar{T} + t_{.05}^{(n-1)} \frac{S_T}{\sqrt{n}} - \mu}{\sigma}\right]$$

Call the $i\underline{th}$ standard normal random variable U_i. Let all normalized values be equal to some subscripted variable, U_i.

Then:

$$P\left[X_f\right] = P\left[U_1 \leq \frac{\bar{T} - \mu}{\sigma} + \frac{t_{.05}^{(n-1)} \frac{S_T}{\sqrt{n}}}{\sigma}\right]$$

With further algebraic manipulation, we have,

$$P\left[X_f\right] = P\left[U_1 \le \frac{\bar{T} - \mu}{\sigma/\sqrt{n}} \cdot \frac{1}{\sqrt{n}} + \frac{t_{.05}^{(n-1)} \, S_T/\sqrt{n}}{\sigma}\right]$$

$$= P\left[U_1 \le \frac{1}{\sqrt{n}} U_2 + \frac{t_{.05}^{(n-1)} \, S_T}{\sigma\sqrt{n}}\right]$$

$$= P\left[U_1 - \frac{1}{\sqrt{n}} U_2 \le t_{.05}^{(n-1)} \frac{1}{\sqrt{n}} \frac{S_T}{\sigma}\right]$$

The variance of the two normalized and independent values, U_1 and U_2, can be found from the equation:

$$\operatorname{Var}\left(U_1 - \frac{1}{\sqrt{n}} U_2\right) = \operatorname{Var} U_1 + \frac{1}{n} \operatorname{Var} U_2$$

$$= 1 + \frac{1}{n}$$

We now have:

$$P\left[X_f\right] = P\left[\frac{U_1 - \frac{1}{\sqrt{n}} U_2}{\sqrt{1 + \frac{1}{n}}} \le \frac{t_{.05}^{(n-1)} \frac{1}{\sqrt{n}} \frac{S_T}{\sigma}}{\sqrt{1 + \frac{1}{n}}}\right]$$

$$= P\left[U_3 \le \frac{t_{.05}^{(n-1)} \frac{1}{\sqrt{n}} \sqrt{\frac{S_T^2}{\sigma^2} \cdot \frac{(n-1)}{(n-1)}}}{\sqrt{1 + \frac{1}{n}}}\right]$$

Since $\sqrt{\frac{S_T^2}{\sigma^2} \Big/ (n-1)}$ is the square root of a chi square random variable, ψ^2, with n-1 degrees of freedom,

$$P\left[X_f\right] = P\left[U_3 < \frac{t_{.05}^{(n-1)} \frac{1}{\sqrt{n}} \sqrt{\frac{\psi^2_{n-1}}{n-1}}}{\sqrt{1+\frac{1}{n}}}\right]$$

$$= P\left[\frac{U_3}{\sqrt{\frac{\psi^2_{n-1}}{n-1}}} \leq \frac{t_{.05}^{n-1} \frac{1}{\sqrt{n}}}{\sqrt{1+\frac{1}{n}}}\right]$$

The term $\frac{U_3}{\sqrt{\frac{\psi^2_{n-1}}{n-1}}}$ corresponds to a t distribution with n-1 degrees of freedom.

The above inequality can then be written:

$$P\left[X_f\right] = P\left[t^{n-1} \leq \frac{t_{.05}^{n-1}}{\sqrt{n+1}}\right]$$

In our case, where n = 3,

$$P\left[X_f\right] = P\left[x_f \leq \bar{T} + t_{.05}^{(2)} \frac{S_T}{\sqrt{3}}\right] = P\left[t^{(2)} \leq \frac{t_{.05}^{(2)}}{\sqrt{4}}\right] = .859$$

Thus, the probability that a future value is less than or equal to the upper bound of the mean of the population is 85.9%.

To increase this probability to 95%, we want:

$$P\left[x_f \leq a\,(s)\right] = .95$$

where a (s) is some function of the sample.

The function a (s) can be determined, as follows:

$$P\left[t^{(n-1)} \leq t^{(n-1)}_{.05} \right] = .95$$

Since $P\left[x_f \leq \bar{T} + t^{(n-1)}_{.05} \frac{S_T}{\sqrt{n}} \right] = P\left[t^{n-1} \leq \frac{t^{(n-1)}_{.05}}{\sqrt{n+1}} \right]$

then

$$P\left[x_f \leq \bar{T} + \left(\sqrt{n+1}\right) t^{(n-1)}_{.05} \left(\frac{S_T}{\sqrt{n}} \right) \right] = P\left[t^{n-1} \leq t^{(n-1)}_{.05} \right] = .95$$

Therefore:

$$a\ (s) = \bar{T} + \sqrt{n+1}\ t^{(n-1)}_{.05} \left(\frac{S_T}{\sqrt{n}} \right)$$

and the .90 confidence interval for a future value x_f is:

$$\bar{T} - \left(\sqrt{n+1}\right)\left(t^{(n-1)}_{.05} \right)\left(\frac{S_T}{\sqrt{n}} \right) \leq X_f \leq \bar{T} + \left(\sqrt{n+1}\right)\left(t^{(n-1)}_{.05} \right)\left(\frac{S_T}{\sqrt{n}} \right)$$

Substituting values for the mean and standard deviation for each of the two samples, BA (1) and BA (2), we arrive at the intervals presented in Section 4.

TABLE C-1

BA 1

RATIO OF ACTUAL EXPENDITURES TO PLANNED OBLIGATIONS

Fiscal Year '74 Month		Fiscal Year '75 Month		Fiscal Year '76 Month	
1.	.983	13.	.967	25.	.992
2.	1.021	14.	.996	26.	.985
3.	.951	15.	.851	27.	.952
4.	.954	16.	1.072	28.	1.001
5.	.985	17.	.997	29.	.933
6.	.988	18.	.987	30.	1.039
7.	.990	19.	1.002	31.	.987
8.	.987	20.	.988	32.	.996
9.	.977	21.	1.000	33.	.988
10.	.992	22.	1.016	34.	1.050
11.	.987	23.	.983	35.	.969
12.	.954	24.	.964	36.	.934
Average	.981	Average	.984	Average	.984

TABLE C-2

BA 1

RATIO OF ACTUAL EXPENDITURES TO ACTUAL OBLIGATIONS

Fiscal Year '74 Month		Fiscal Year '75 Month		Fiscal Year '76 Month	
1.	.994	13.	.991	25.	.992
2.	.997	14.	.996	26.	.994
3.	.978	15.	.974	27.	.992
4.	.987	16.	1.014	28.	1.003
5.	.969	17.	.966	29.	.946
6.	.987	18.	.988	30.	1.045
7.	.989	19.	1.001	31.	.998
8.	1.004	20.	1.016	32.	1.012
9.	.983	21.	.997	33.	.994
10.	.998	22.	1.013	34.	.998
11.	1.010	23.	.988	35.	1.002
12.	.970	24.	1.012	36.	.935
Average	.989	Average	.996	Average	.992

TABLE C-3

BA 2

RATIO OF ACTUAL EXPENDITURES TO

PLANNED OBLIGATIONS

Fiscal Year '74 Month		Fiscal Year '75 Month		Fiscal Year '76 Month	
1.	.944	13.	.961	25.	.957
2.	.986	14.	1.015	26.	.990
3.	.970	15.	.994	27.	1.036
4.	.979	16.	.989	28.	.962
5.	1.003	17.	.991	29.	.984
6.	.965	18.	1.023	30.	1.035
7.	1.006	19.	1.000	31.	.955
8.	.985	20.	.967	32.	.965
9.	.977	21.	.993	33.	1.034
10.	.983	22.	1.022	34.	1.014
11.	.988	23.	.980	35.	.985
12.	.978	24.	.930	36.	.967
Average	.981	Average	.989	Average	.990

TABLE C-4

BA 2

RATIO OF ACTUAL EXPENDITURES TO ACTUAL OBLIGATIONS

Fiscal Year '74 Month		Fiscal Year '75 Month		Fiscal Year '76 Month	
1.	.944	13.	.969	25.	.956
2.	.986	14.	1.021	26.	1.000
3.	.983	15.	.992	27.	1.029
4.	.999	16.	.997	28.	.965
5.	1.022	17.	.998	29.	1.000
6.	.966	18.	1.013	30.	1.034
7.	1.027	19.	.994	31.	.961
8.	1.004	20.	.969	32.	.981
9.	1.006	21.	.997	33.	1.038
10.	.988	22.	1.020	34.	1.019
11.	.997	23.	1.006	35.	.985
12.	.981	24.	.941	36.	.956
Average .993		Average .993		Average .993	

APPENDIX D

TRANSFER FUNCTION MODELS

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TRANSFER FUNCTION MODELS

The transfer function model theory described in this appendix describes the formulations and relationships used to analyze the BA1 and B2 data. Other aspects of time series analysis as described in reference 1/ are not discussed since the reference is the best source of information on these topics. Appendix E which follows this one contains a description of the computer programs developed for this analysis and their use.

Transfer Functions Without Noise

If no noise is corrupting the relationship between and input series $\{X_t\}$ and output series $\{Y_t\}$, then the general form of the transfer function with finite parameters which relates the input series to the output series is

$$Y_t = f_o + f_1 Y_{t-1} + f_2 Y_{t-2} + \ldots + f_p Y_{t-p} + g_o X_{t-1} + \ldots + g_q X_{t-q}. \tag{1}$$

Equation (1) says that the current value of the output series can be written as a constant, f_o, plus a linear combination of past values of the output series and a linear combination of the current and past values of the input series. The f's and g's are constant parameters of the transfer function. Let B be the backshift operator. This linear operator acts in the following way:

$$B^i X_t = X_{t-i}$$

Using the backshift operator equation (1) can be rewritten as

$$F(B)\, Y_t = f_o + G(B)\, X_t \tag{2}$$

where $\quad F(B) = 1-f_1B-f_2B^2 - \ldots - f_pB^p$

and $\quad G(B) = g_o+g_1B + g_2B^2 + \ldots + g_qB^q$

Equation (1) can be manipulated so that Y_t can be expressed as a function of only current and past values of the input series by dividing both sides of equation (2) by F(B):

$$Y_t = F^{-1}(B)f_o + F^{-1}(B)G(B)X_t \tag{3}$$

1/ Box and Jenkins, Time Series Analysis: Forecasting and Control, Holden-Day, San Francisco, 1976.

The first term on the right, $F^{-1}(B)f_o$ is just a constant. The second term, depending on the order if G(B) and F(B) will be either a finite or infinite polynomial in B so that equation (3) has the form:

$$Y_t = c_o + v_o X_t + v_1 X_{t-1} + v_2 X_{t-2} + \dots \quad (4)$$

$$= c_o + \sum_{i=0}^{\infty} (v_i B^i) X_t$$

$$= c_o + V(B) X_t \quad (5)$$

where $V(B) = F^{-1}(B)\, G(B)$.

The v_i in equation (4) are called the <u>transfer function weights.</u> Estimation of the parameters of a model is most easily done if only a finite number of parameters are estimated. Consequently, the model estimation procedure described in appendix E estimates the parameters of equation (1) rather than the possibly infinite parameters of equation (4).

<u>Gain of the Transfer Function</u>

The gain, g, if a transfer function is given by

$$g = \sum_{i=0}^{\infty} v_i = \frac{g_o + g_1 + \dots + g_g}{1-f_1-f_2-\dots f_p} \quad (6)$$

The gain of a transfer function is a measure of the input of a change in the input series on the output series. For instance, if c_o in equation (4) were zero and $X_t = \emptyset$ for $t \leq t'$, then $Y_t = \emptyset$ for $t \leq t'$. Now suppose $X_t = 1$, $X_t = \emptyset$ for $t > t'$, then

$$Y_{t'} = v_o$$

$$Y_{t'+1} = v_1$$

$$Y_{t'+2} = v_2$$

$$\vdots$$

$$Y_{t+i} = v_i$$

$$\vdots ,$$

and

$$\sum_{t=t'}^{\infty} Y_t = \sum_{i=0}^{\infty} v_i = g.$$

Thus the gain, g, is a scalar measure of the cumulative effect on the output series of a unit change in the level of the input series.

Transfer Functions With Noise

In most cases of interest the relationships between the input series and output series will include a component which can not be explained in a deterministic model. This unpredictable component is usually referred to as "noise". With noise present, equation (3) becomes

$$Y_t = F^{-1}(B)f_o + F^{-1}(B)G(B)\ X_t + N_t. \tag{7}$$

If the N_t are independently normally distributed random variables with means equal to zero and equal variances then N_t is written as a_t indicating that no further transformations can be made to reduce the unpredictable components of the model. If, on the other hand, the N_t are correlated and have non zero mean, the model can be adjusted to change the constant, f_o, and transform N_t by writing it as follows:

$$N_t = E^{-1}(B)H(B)\ a_t$$

where $E(B) = 1-e_1 B-e_2 B + \ldots + e_{p'} B^{p'}$

and $H(B) = h_o + h_1 B + h_2 B^2 + \ldots + h_{q'} B^{q'}$

The total transfer function model can then be written as

$$Y_t = c_o + F^{-1}(B)G(B)\ X_t + E^{-1}(B)H(B)\ a_t \tag{8}$$

where the a_t are independently distributed normal randon variables with zero means and equal variances.

Forecasting Errors

If the model contains no noise then forecasts are made using either equation (1) or (4) and there will be no errors in the forecast. If noise is present, then equation (8) will be used to forecast or the following equations can be used:

$$E(B)F(B)\ Y_t = E(B)\ f_o + E(B)G(B)\ X_t + F(B)H(B)\ a_t. \tag{9}$$

Equation (9) will have a finite number of terms. In either case, forecasts are made assuming that future values if a_t will be zero since zero is the expected value for the random value. Errors in the forecast result from the a_t not being zero. However, the error will have a distribution based on the standard deviation of the a_t. Suppose equation (8) is written as

$$Y_t = c_o + \sum_{i=0}^{\infty} v_i X_{t-i} + \sum_{i=0}^{\infty} W_i a_{t-i}\ . \tag{10}$$

Also let $\hat{Y}_t(k)$ be a forecast of Y_{t+k} made from period t. Then $\hat{Y}_t(k)$ is calculated or follows

$$\hat{Y}_t(k) = c_o + \sum_{i=0}^{\infty} v_i X_{t+k-i} + \sum_{i=1}^{\infty} W_i a_{t+k-i}$$

since $a_{t'}$ is assumed to be zero for $t' > t$. Therefore, the error in the forecast is

$$Y_{t+k} - \hat{Y}_t(k) = \sum_{i=0}^{k-1} W_i a_{t+k-i}$$

The mean of the forecast is zero since the mean of each of the a_t is zero. The variance of the forecast is

$$\text{Variance}\ (Y_{t+k} - \hat{Y}_t(k)) = \text{Variance}\ \left(\sum_{i=0}^{k-1} w_i a_{t+k-i}\right)$$
$$= \sum_{i=0} w_i^2 \sigma_a^2$$

Where σ_a is the standard deviation of the random noise components, a_t. The variance of a cumulative forecast for n periods can be found as follows:

$$\text{Cumulative error} = \sum_{i=1}^{n} (Y_{t+i} - \hat{Y}_t(i)) = \sum_{i=1}^{n} \sum_{k=0}^{i-1} w_k a_{t+i-k}$$
$$= w_o a_{t+1}$$
$$+ w_o a_{t+2} + w_1 a_{t+1}$$
$$+ w_o a_{t+3} + w_1 a_{t+2} + w_2 a_{t+1}$$
$$\vdots$$

$$+ w_o a_{t+n} + w_1 a_{t+n-1} + \dots + w_{n-1} a_{t+1}$$

$$= \sum_{i=1}^{n} a_{t+i} \sum_{k=0}^{i-1} w_k$$

Hence

$$\text{Variance of cumulative error } \left[\sum_{i=1}^{n} (Y_{t+i} - \hat{Y}_t(i)) \right] = \sum_{i=1}^{n} \left(\sum_{k=0}^{i-1} w_k \right)^2 \sigma_a^2$$

$$= \sigma_a^2 \sum_{i=1} \left(\sum_{k=o}^{i-1} w_k \right)^2$$

The remainder of this appendix shows the calculations made to arrive at the values shown in the main body of this report for the BA(1) and BA(2) accounts.

BA(1)

Deviations from linear trends:

$$x_t = X_t - .238t - 105.8$$

$$y_t = Y_t - .253t - 103.6$$

Transfer function model for deviations from trends:

$$y_t = (.269 + 250B - 180B^2)\, x_t + (1 + .296B)^{-1} a_t \qquad \sigma_a^2 = 6.69$$

$$= (.269 + .250B - .180B^2)\, x_t + \sum_{j=0}^{\infty} (.296)^j a_{t-j}$$

$$\text{Gain of the system} = g = \frac{.269 + .250 - .180}{1} = .339$$

$$\text{variance of } (y_{t+k} - y_t(k)) = V(k) = \sigma_a^2 \sum_{j=0}^{k-1} (.296)^j = 6.69 \sum_{j=0}^{k-1} (.296)^j$$

variance of cumulative error for n periods =

$$\tilde{V}(n) = \sigma_a^2 \sum_{=1}^{n} \left(\sum_{k=0}^{i-1} (.296)^k \right)^2$$

$$= 6.69 \sum_{i=1}^{n} \left(\sum_{k=0}^{i-1} (.296)^k \right)^2$$

BA(2)

Deviations from linear trends:

$$x_t = X_t - .298t - 309.3 \quad \text{(Planned obligations)}$$

$$y_t = Y_t - .404t - 303.1 \quad \text{(Actual expenditures)}$$

Transfer function model for deviations from trends:

$$y_t = (.515 + .211B + .450B^2)x_t + a_t \qquad \sigma_a^2 = 51.05$$

(Note $w_0 = 1$, $w_i = \emptyset$ for $i > 0$)

Gain of the system $= g = \dfrac{.519 + .211 + .450}{1} = 1.180.$

Variance of $(y_{t+k} - \hat{y}_t(k)) V(k) = \sigma_a^2 = 51.05$

Variance of cumulative error for m periods $= \bar{V}(n) = \sigma_a^2$

APPENDIX E

USER'S GUIDE TO THE BOX-JENKINS PROGRAM SET

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USER's GUIDE TO THE BOX-JENKINS PROGRAM SET

The following is a discussion of a set of six computer programs designed to aid the user in fitting a predictive model to two series of observations. The discussion assumes that the reader has some familiarity with the procedure employed, Box-Jenkins analysis. The reader is referred to Appendix D for an explanation of the time series analysis method. Also included here are several caveats concerning the use of these programs, followed by some suggestions for their future modification.

In brief, the user, with the help of these programs, will attempt to explain or predict the present or future performance of one series of data, in this case actual expenditures, in terms of its past performance, and in terms of the present and past performance of another series, in this case planned obligations. The user and the programs will determine how many previous months are to be included in the model and what the coefficients of the previous actual expenditures and planned obligations will be. The first three programs, viz. USID, USPE, and USES, aid in fitting a Box-Jenkins single-series model to the planned obligations. The last three, viz. UTID, UTPE and UTES use the planned obligations model to construct a transfer function model for actual expenditures.

A Box-Jenkins single-series model, the type used for planned obligations, attempts to explain or predict planned obligations for a given month in terms of previous months' planned obligations, plus an unexplained component called "noise". The model has two sets of coefficients of past planned obligations: a finite set, what Box and Jenkins call "autoregressive" , for short term effects, and an infinite set, what Box and Jenkins call "moving average," for effects that take a long time to die out. The resulting model is a combination of the two.

A transfer function model is a two-stage model. The first stage is called a "transfer function." It explains or predicts actual expenditures in terms of past actual expenditures, and planned obligations at and previous to the delay

time. The delay time is the time it takes a planned obligation to affect an actual expenditure. There is a second representation for the transfer function. Since present actual expenditures can be expressed in terms of planned obligations and past actual expenditures, and those past actual expenditures can be expressed in terms of more planned obligations and further past expenditures, and so on *ad infinitum* the present actual expenditures can be expressed in terms of an infinite series of planned obligations. The coefficients in this infinite series are called the "transfer function weights." A transfer function will almost always leave some unexplained variability in the observed data, variability which we will refer to as noise. The less noise there is in a transfer function model, the better it will predict. For this reason and to give the noise some nice statistical properties, Box and Jenkins apply a second stage: a single-series model *to the noise*. This second stage is called a "noise model." Like the single-series model mentioned above, the noise model consists of an autoregressive (finite) part and a moving average (infinite) part. It has the effect of adding more months past actual expenditures and planned obligations to the model and modifying the coefficients of those expenditures and obligations already in the model. Thus, it can be thought of as a correction to the transfer function. Unexplained variability left over after the noise model has been fitted will be referred to below as the final noise. In sum, the transfer function model is the combination of two parts, the transfer function and the noise model.

The six programs were integrated to such an extent that all the information the user needs to supply, except for the planned obligation and actual expenditure raw data, are put into the system in response to direct requests by the program. The raw data should be entered into two files called XDATA, for planned obligations, and YDATA, for actual expenditures. The data should be entered in chronological order with one data item, i.e., the dollar figure for one month, on a line.

The first program, USID, prints out several summary statistics that can aid the user in identifying the number of coefficients that should be included in the single-series model for planned obligations.[1/] It is not always the case

---

1/ The moving average portion of a single-series model is the inverse of a polynomial, and thus it can be identified by a finite number of coefficients.

that one can fit a good single-series model to a series of observations. It may be that the amount of money obligated or spent may vary widely over time. It may also happen that not only the amount itself but also the rate at which the amount changes from month to month varies widely over time. In these cases it may be necessary to "difference" the raw data to remove these wide variations over time, as explained in the chapter called "Nonstationary Linear Models" in Box and Jenkins. The first difference of a series is another series. The first element of the first difference series is equal to the difference between the second and first elements of the original series, the second element of the first difference series is equal to the difference between the third and second elements of the original series and so on. Differencing a series once will remove the variation over time of the level of a series. The second difference of a series is the first difference of the first difference and so on. The second difference removes both variability over time of the amount obligated or spent and the variability over time of the month-to-month change in amount. Differences higher than the second are almost never needed in practice. USID needs to know whether the user is planning to do a transfer function analysis and what the characteristics of the planned obligations data are. USID determines the first by asking for the number of input streams the user wants to use. If the user enters "2" then the program assumes that he/she wishes to perform a transfer function analysis, if the user has provided only one, then the program assumes that he/she wishes to do single-series analysis only. The characteristics USID needs are the number of data point per series, the degree of differencing required - two or less - and the number of terms in the autocorrelation and partial autocorrelation functions which should be calculated. The program refers to these characteristics as "N, DIFF, MAXCOR." The autocorrelation and partial autocorrelation functions describe how planned obligations affect present planned obligations. Their interpretations discussed at great length in Box and Jenkins' book, under "Linear Stationary Models." USID calculates the two differenced series, one for planned obligations and one for actual expenditures, and the autocorrelation and partial autocorrelation functions for the planned obligations. The differenced series for

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BUPERS MPN EXPENDITURE ESTIMATING.(U)

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2 OF 2

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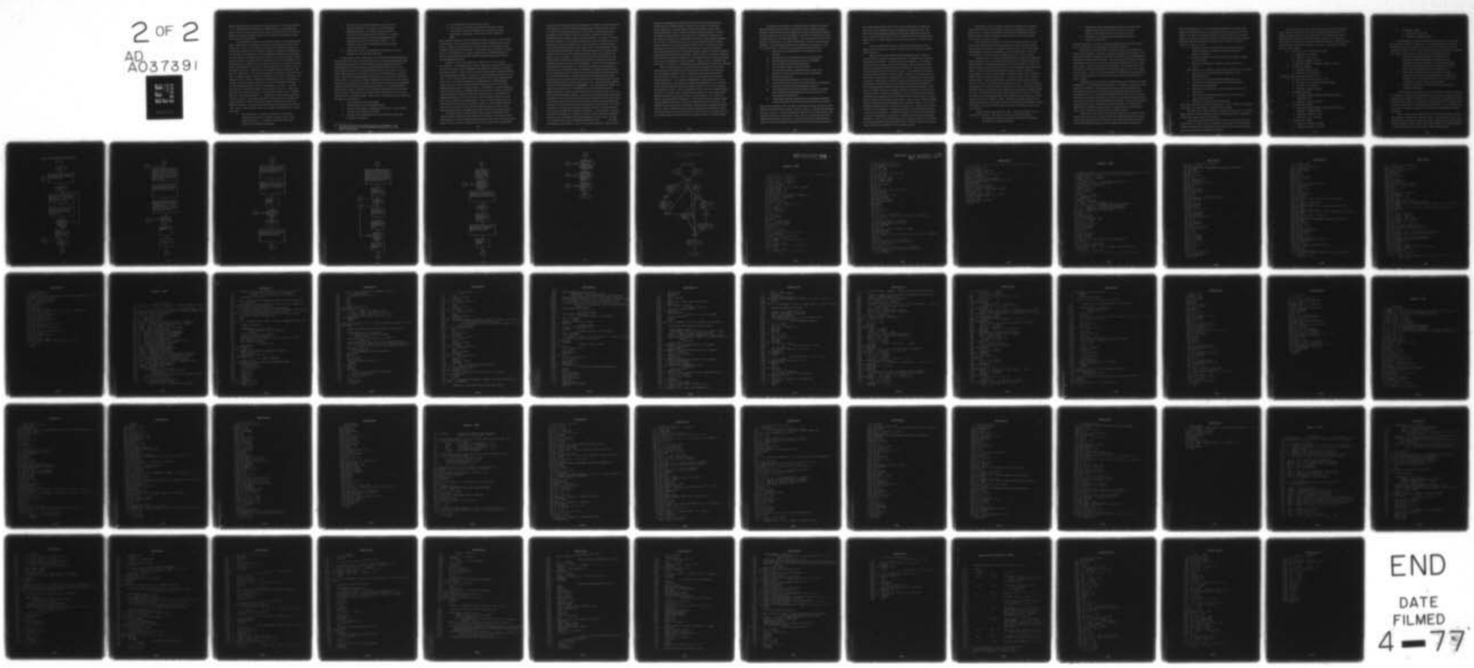

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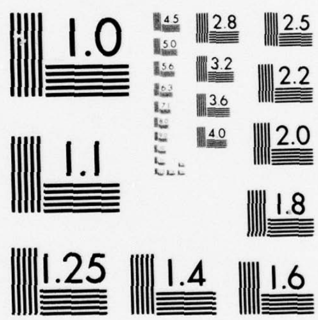


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

planned obligations and the two functions are printed out. If the user answers "1" to "CREATE OUTPUT FILES WITH CURRENT FILES," the two differenced series, with the sample means removed, will be passed to UTID and UTES, the differenced planned obligations series will be passed to USES, and the functions will be passed to USPE.

Once finished with USID the user should proceed to the second program, USPE. USPE produces preliminary estimates for the coefficients of the single-series model, that is, the coefficients of past months' planned obligations. The program prompts the user by writing "ENTER P,Q, EPSILON, AND MAXITER." P is the number of coefficients in the autoregressive (finite) part of the model, Q is the number of coefficients needed to describe the moving average (infinite) part of the model, and EPSILON is the tolerance to which the coefficients will be calculated. The program uses an iterative procedure to calculate the coefficients, and MAXITER is the maximum number of iterations the program will perform before giving up. Reasonable values for EPSILON and MAXITER are .001 and 100, respectively. If the estimates cannot be computed to the desired accuracy, a message stating the reason for failure will be printed. Otherwise, the estimates will be printed, autoregressive coefficients in the column labeled "PHI(I)" and moving average coefficients in the column labeled "THETA(I)." If the user is dissatisfied with this set of estimates -- see below -- he/she should specify that the file IWHITE not be created at this time. This is done by pushing the carriage return key. This will cause USPE to query "CHANGE INPUTS?"; the user should reply "1." Then the user should specify alternate values for P and Q. This process should be repeated until the user finds the most satisfactory P and Q at which time he/she should direct that the file IWHITE be created. The program will pass these initial estimates to USES and stop. Here are some reasons why the user might be dissatisfied with a particular model:

1. The coefficients lie outside the stability or invertibility regions defined by Box and Jenkins in their chapter "Linear Stationary Models." An unstable or non-invertible model is not valid and <u>should not be used</u>.

2. The user feels the proposed model has too much unexplained variability. The variance of the differenced planned obligations series with no model is listed in row zero of the column labeled "COV(I)," and the variance of the differenced series using the proposed model is listed above the table and is labeled "VAR AT ." The better the model, the less VAR AT should be in relation to row zero of COV(I).
3. Because some of the coefficients are near zero the user may feel that too many are being estimated.

Program number three, USES, uses a non-linear least squares technique, described in Section 7.2 of Box and Jenkins' book, to produce approximate maximum likelihood estimates for the coefficients in the single-series model. 2/ This program asks for the following items of information from the user: the number of desired terms of the autocorrelation function for the noise, the mean of the differenced data, and whether or not the user is allowing for a seasonal effect. The number of autocorrelation terms need not be the same as that specified for USID. If the user used USID to difference the data the mean will be zero. If the user is using USID and/or USPE, no allowance will be made for seasonality. USES then begins the iterative least squares procedure. At every iteration the program prints "BETA," followed by the coefficient estimates for the current iteration, and "SBO," followed by the estimated likelihood function for the current iteration and the previous iteration. When, and if, the iterative process converges the following are printed out:

1. Final estimates of the coefficients.
2. A final estimate of the likelihood function.
3. The covariance matrix, standard deviation vector, and correlation matrix for the coefficient estimates.
4. The noise series resulting from the single-series model using the above coefficients.

2/ An understanding of maximum likelihood estimation is not necessary. For a discussion of the topic see any good introductory statistics text, e.g., the book by Hogg and Craig.

5. The estimated variance of the noise series.
6. The estimated autocorrelation function of the noise series.
7. A chi-square statistic evaluating how well the noise series approximates white noise. White noise will be explained below.

If the standard deviations of the coefficient estimates are large, where "large" is subjective, .20 for example, the estimates of the coefficients are not very precise. There is not much that can be done to improve the precision of the estimates except procure more data. If correlations among estimates are close to 1 or -1, the estimates are suspect, because high correlation between estimates may mean that the estimated likelihood function poorly approximates the true likelihood function.

Whether or not the correlations are "close" to 1 or -1 is a subjective decision. The estimated noise variance should be compared with line zero of COV (I) in program USPE to determine how effective the model is in reducing the amount of noise. White noise is a series of independent, identically distributed normal random variables. The terms of the autocorrelation function are all zero. The chi-square statistic shows how well the noise series approximates white noise. A poor approximation is an indication that a different model should be tried. All this assumes that the iterative process will converge. Unfortunately this does not always happen. If estimates at a given iteration lie outside the invertibility or stability regions then the noise values or the likelihood function may overflow the word size of the computer. From then on the programs calculations will be incorrect, so the user should stop the program and go back to USPE to try another model. Also it sometimes happen that the procedure will seem to take an eternity to converge. The estimates produced in such a case should be viewed with scepticism, and th user may elect to halt the program before convergence and return to USPE to try another model.

The fourth program, UTID, performs the same sort of analysis for the transfer function model that USID performs for the single-series model. Where USID produces several functions useful in identifying the order of a single series model, that is, how many coefficients are in the autoregressive part and how

many in the moving average part, UTID produces a number of functions useful in in identifying the order of a transfer function model. There are five parts to the order of the transfer function model: the number of past months' actual expenditures in the transfer function, the number of months' delay before planned obligations begin to affect actual expenditures, the number of month's planned obligations in the transfer function, the number of coefficients in the autoregressive part of the noise model, and the number of coefficients describing the moving average part of the noise model. For mathematical reasons the third element in the order, number of planned obligations, is given as one less than the number of past months used; there will be a zeroth term in the model to take care of this. To study the order of the transfer function model UTID takes the single series model found in USES and applies it to both the planned obligations and the actual expenditures. This is called "prewhitening" the obligations and expenditures. UTID then prints out the autocorrelation function for the prewhitened planned obligations, the autocorrelation function for the prewhitened actual expenditures, the crosscorrelation function between the two prewhitened series, and estimates of the transfer function weights (See page B-2), the autocorrelation function for the resulting noise series, and partial autocorrelation function for the noise series. The first column, RAA(K), contains the autocorrelations for obligations; the second column, RBB(K), contains the autocorrelations for expenditures; the third and fourth columns RAB(K) and RAB(-K), contains the crosscorrelations; the fifth column, V(K), contains the transfer function weights. The noise autocorrelations and partial autocorrelations are in the first and second columns respectively of the second table. The crosscorrelations in column three are a measure of how much planned obligations in a given month affect actual expenditures in later months. The crosscorrelations in column four constitute a measure of how much actual expenditures in a given month affect planned obligations in later months. The crosscorrelations in column four constitute a measure of how much actual expenditures in a given month affect planned obligations in a later month. Of these five columns the one which should most concern the user is the fifth, the transfer function weights. There are two reasons for this. First, in their

section on identification of transfer function models Box and Jenkins show how to relate the transfer function weights to the number of months past actual expenditures, the delay before planned obligations begin to affect actual expenditures, and the number of months planned obligations. Second, the number of weights that the user thinks to be significant determine how the program calculates the autocorrelation and partial autocorrelation functions for the noise. UTID first asks the user how many transfer function weights he/she would like to see and how many he/she wishes the program to use in calculating the noise autocorrelation and partial autocorrelation functions. The program will print table of the transfer function weights and noise autocorrelation and partial autocorrelation functions. At this point, the user may change the number of transfer function weights to be calculated and/or the number of weights to be used in calculating the noise statistics. When the user is satisfied with the current set of weights, UTID will pass the information on to UTPE and will stop.

UTPE, the fifth program, presents preliminary estimates for the coefficients of the transfer function model in much the same manner that USPE presents preliminary estimates for the coefficients in the single-series model The program first requests "R,S,B," where R is the number of past-months actual expenditures. The estimated coefficients are then printed out. If the coefficients for past expenditures are outside the stability region or if the user thinks another transfer function may provide a better fit, the user can specify an alternate R,S, and B. When a satisfactory transfer function is obtained UTPE moves on to the noise model. Since the noise model is a single-series model applied to the noise, this part of UTPE is a copy of USPE: it asks for P the number of autoregressive coefficients, Q, the number of moving average coefficients, EPSILON, tolerance to which the coefficients will be calculated, and MAXITER the maximum number of iterations the preliminary estimation procedure will do. When a satisfactory noise model is obtained the program asks if the user wishes to try a new transfer function. If the answer is yes UTPE starts all over; if the answer is no UTPE passes the initial estimates to UTES and stops.

The final program is UTES. It takes the initial estimates of transfer function coefficients and performs the nonlinear least squares estimation procedure used in USES to produce approximate maximum likelihood estimates. The only information the user must supply is the number of terms for the autocorrelation and cross correlation functions. The same number of terms is computed for each function. Like USES, UTES prints a number of estimates and statistics. Box and Jenkins discuss the interpretation in sections 7.1 and 11.3 of their book. These are the estimates and statistics produced:

1. Estimates of the transfer function coefficients at each iteration.
2. An estimate of the likelihood function at each iteration.
3. Final estimates of the transfer function coefficients.
4. Final estimate of the likelihood function.
5. The estimated variance of the final noise.
6. The covariance matrix, standard deviation vector, and correlation matrix of the estimates of the coefficients.
7. The final noise series.
8. The autocorrelation function of the final noise.
9. A chi-square statistic comparing the final noise autocorrelation function to a white noise autocorrelation function.
10. The crosscorrelation function between the noise of the single-series model for planned obligations and the final noise of the transfer function model.
11. A chi-square statistic comparing the crosscorrelation function to the crosscorrelation function between two white noise series.

Most of these statistics have the same interpretation as those given the corresponding statistics printed by USES. However, there is a different interpretation put on the last four. If the autocorrelation function does not look like the autocorrelation function of a white noise series, that is an indication that an incorrect transfer function was used. If the crosscorrelation function does not look like the crosscorrelation function between two white noise processes but

the autocorrelation function does look like the autocorrelation function of white noise, this indicates that an incorrect noise model was used. All terms in the crosscorrelation function between two white noise series are zero. As was the case in USES, there are times when the least squares procedure will fail. If that happens, the user should go back to UTPE and start again.

The user will find in Figure E-1 a flowchart describing the action taken by the programs and by the user at every stage, including the options open to the user.

There are four things of which the user should beware. One, the possible failure of the least squares procedure, has already been discussed. The second is exceeding array limits set in the programs. Due to space limitations of the computer on which the programs were written, the longest series the program can handle has fifty observations. The maximum number of coefficients which can be estimated is ten. In all programs the maximum number of autocorrelations allowed is thirty. Third, the user should be sure that he/she knows what set of coefficients are being passed from one program to another. USPE passes to USES the last set of initial estimates calculated. UTID passes to UTPE the last set of transfer function weights and the last noise autocorrelation and partial autocorrelation functions calculated. UTPE passes to UTES the last set of transfer function coefficients and the last set of noise function coefficients calculated. If the user thinks one set of coefficients has been passed when in reality another set has been passed, the user will very likely reach erroneous conclusions. Fourth, the user should ascertain that the programs have been modified for the FORTRAN compiler in use by the particular computer system on which they are to be run. Unlike most FORTRAN compilers, the compiler for which these programs were written does not allow carriage control characters in FORMAT statements. Also its rules for inserting a comment or continuing a statement on a following line differ from standard FORTRAN. Further, the compiler allows zero or negative indexing for DO-loops. Other incompatibilities may exist between the FORTRAN in which the programs were written and the FORTRAN in use on another system.

If the user wishes to bypass or omit some programs in the sequence he/she can do so by creating the files required by the programs the user wants to use. Figure E-2 illustrates how the files are passed from one program to another, and the following paragraphs describe the various files, their purposes, and their formats.

The most important files, the ones the casual user need worry most about, are the files containing the two sets of raw data. The user should put the planned obligations, in chronological order, into a file called XDATA and should put the actual expenditures, in chronological order, into a file called YDATA. Each file is read, one datum to a line, in F10.3 format.

Probably, the two next most important files are the files of transformed data, XFILE and YFILE. To generate XFILE from XDATA, the program USID performs the degree of differencing requested by the user, finds the mean of the differencedseries, and subtracts the mean from each element of the differenced series. YFILE is generated from YDATA in the same manner. XFILE and is an input file to USES, and both XFILE and YFILE are input files to UTID and UTES. There are several reasons why a user might wish to use a different XFILE or YFILE. USID assumes that the sample mean of the differenced data is the true mean of the process which generated the data. If the user believes that that is not the case but does not know the true mean, he/she can construct an XFILE using the data without the sample mean removed and let USES estimate the mean. If the user believes that he/she does know the true mean, he/she can remove the true population mean from the data, create an XFILE and a YFILE, and use those files in UTID and UTES. Both XFILE and YFILE should be constructed as follows: the first line consists of the number of data points, written in I4 format, and each succeeding line contains one monthly datum written in F12.6 format.

One other file is constructed by USID. That file is DUSPE, and it is an input file for USPE. Three types of data are contained in DUSPE:

1. The largest time lag for which an autocorrelation coefficient is calculated, written in I4 format.

2. Coefficients in the autocorrelation function of the differenced planned obligations series from the zeroth term to the largest, written one number to a line in F12.6 format.

3. The mean of the differenced planned obligations series, written in F12.6 format.

The user may wish to construct an alternate DUSPE file to see what estimates would be produced from an alternate autocorrelation function.

The products of program USPE, the initial estimates of coefficients in the single-series model, are passed to program USES via the file IWHITE. The first record of IWHITE contains the number of coefficients in the autoregressive (finite) part of the single series model. The second record contains the number of coefficients used to describe the moving average (infinite) part of the single series model. These are each written in I4 format. The remainder of the file consists of the preliminary estimates of the coefficients, one to a line, written in F12.6 format. A user may wish to construct an IWHITE file to test whether or not the initial estimates have a significant effect on the final estimates produced by USES.

FWHITE is a file consisting of final estimates of the single-series model coefficients. It is produced by program USES. It is written in exactly the same format as file IWHITE. FWHITE is used by program UTID to prewhiten (see discussion of UTID above) both the planned obligations data and the actual expenditures data. It is also used by program UTES to check the crosscorrelation between the noise produced by the single-series model for planned obligations and the final noise for the transfer function model. If the user has several alternate single series models with coefficient estimates, by constructing FWHITE files he/she can develop alternate transfer function models through UTID, UTPE, and UTES without having to run USES each time.

UTID writes a file called PR5OUT which contains rough estimates of the transfer function weight to be used in UTPE to generate preliminary estimates of the three parts of the transfer function: past actual expenditures, present and/or past planned obligations, and the delay before planned obligations

affect actual expenditures. Also contained in PR5OUT are the terms in the autocorrelation function of the noise left after the transfer function has been applied. As USPE uses the autocorrelation function in DUSPE to construct a single series model for planned obligations, so UTPE uses the autocorrelation function in PR5OUT to construct the noise model. PR5OUT is written as follows, one datum to a line:

1. The maximum number of past months for which the transfer function weights are significantly different from zero, written in I4 format.
2. The rough estimates of the transfer function weights, written in F12.6 format.
3. The noise autocorrelation function, also written in F12.6 format.

UTPE produces a file, PR6OUT, which feeds to UTES all of the following:

1. The number of months' past actual expenditures in the transfer function.
2. The number of months' planned obligations less one.
3. The number of months delay before a planned obligation affects actual expenditures.
4. The number of coefficients in the autoregressive part of the noise model.
5. The number of coefficients describing the moving average part of the noise model.
6. Preliminary estimates for all coefficients.

As per usual each line contains only one number. Items 1 through 5 are written in I4 format, the coefficients are written in F12.6 format.

The final file is MODEL, which is created by program UTES. It contains final estimates of all coefficients in the transfer function model. The file is written in the same format as file PR6OUT.

There are several improvements which users may wish to make to the set of programs. Two of the most important are to expand the array bounds to enable the programs to accept longer series and to allow the programs to take into account effects of seasonality in the data.

As the programs now stand, USID can accept a series of length 100, UTID a series of length 300, and USES and UTES series of length 50. As USPE and UTPE do not use the series directly, they can handle any length. If the user's computer system has enough main memory it is advisable to alter USES and UTES to accept series of length at least 100. 32K 16-bit words or 16K 32-bit words is surely enough main memory. For USES the following changes must be made:

1. In every routine in which they are found
   a. dimension "Z" as (100)
   b. dimension "W" as (115)
   c. dimension "RESID" as (115)
2. In subroutine LSQEST dimension "WORK 1" as (115)
3. In subroutine MARQUA
   a. dimension "AT" as (115)
   b. dimension "X" as (10,115)

In UTES the following changes must be made:

1. In every routine in which they are found
   a. dimension "X" as (100), except in MARQUA
   b. dimension "Y" as (100)
   c. dimension "RESID" as (100)
2. In subroutine ESTIM
   a. in COMMON block SERIES change "DUMMY (65)" to "DUMMY (115)."
   b. dimension "WORK1" as (115)
3. In subroutine MARQUA
   a. in COMMON block SERIES "DUMMY (65)" should be changed to "DUMMY (115)"
   b. dimension "RESIDT" as 100
   c. dimension "X" as (10,100)
4. In subroutine CRESID
   a. dimension "SCRIPT" as (100)
   b. dimension "SMALLN" as (100)

5. In subroutine STATS7

a. dimension "A" as (100)

b. dimension "ALPHA" as (100)

As the package is currently written only USES allows the user to take into account the effects of seasonality. Seasonality in transfer functions is not addressed in Box and Jenkins' book; they give no directions on how to modify UTID, UTPE, or UTES. Here are three general suggestions to be followed in converting USID and USPE so that they can do seasonal analysis.

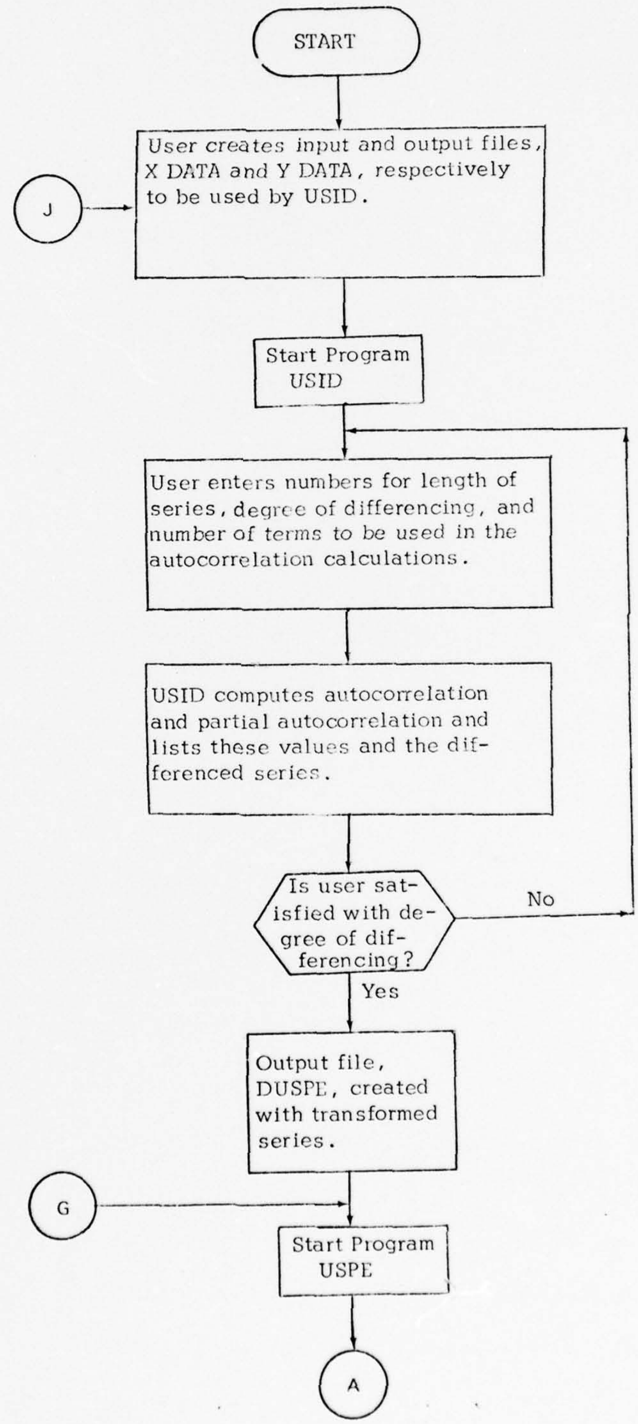
1. Give USID the capacity to do seasonal differencing. Whereas in regular differencing an observation is subtracted from the next observation, in seasonal differencing an observation is subtracted from the observation S months later, where S is the period of the seasonal effect.
2. Allow USPE to determine initial estimates of the autoregressive and moving average coefficients of a single series seasonal model. See Box and Jenkins' book, chapter 9, for a discussion of single series seasonal models.
3. Change the format of file IWHITE to allow the inclusion of seasonal coefficients.

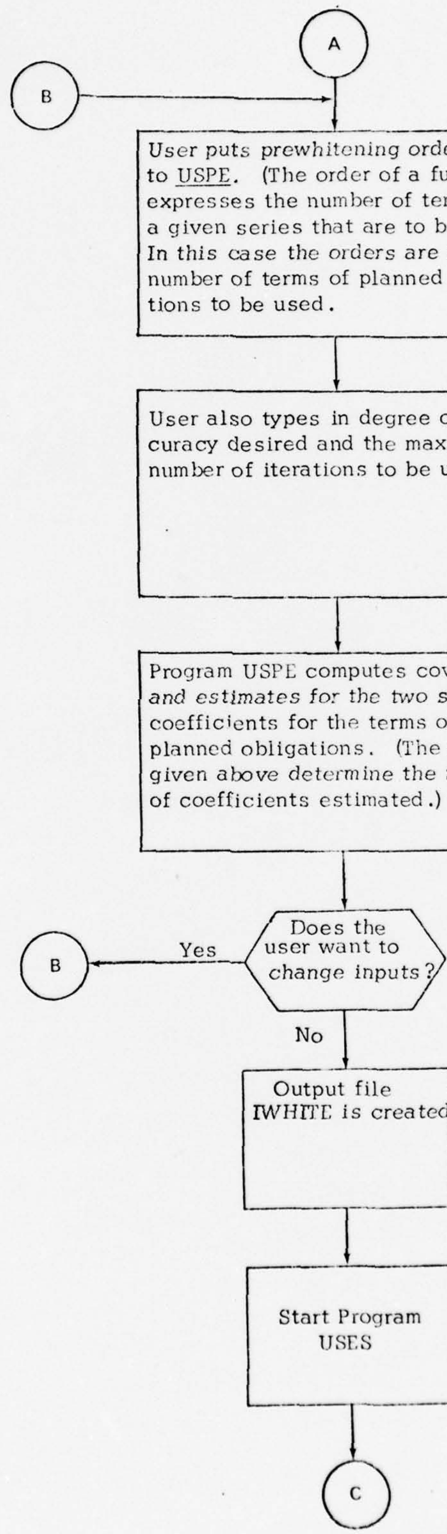
A third possible embellishment, one for which current analysis indicates the planned obligations/actual expenditures have no need, is to enable the programs to perform logarithmic or power, e.g. square root, transformations on the undifferenced raw data. This could be done with relative ease by causing USID to ask if the user wishes to have the data transformed. If so, then USID would ask for the transformation parameters and perform the transformations before proceeding.

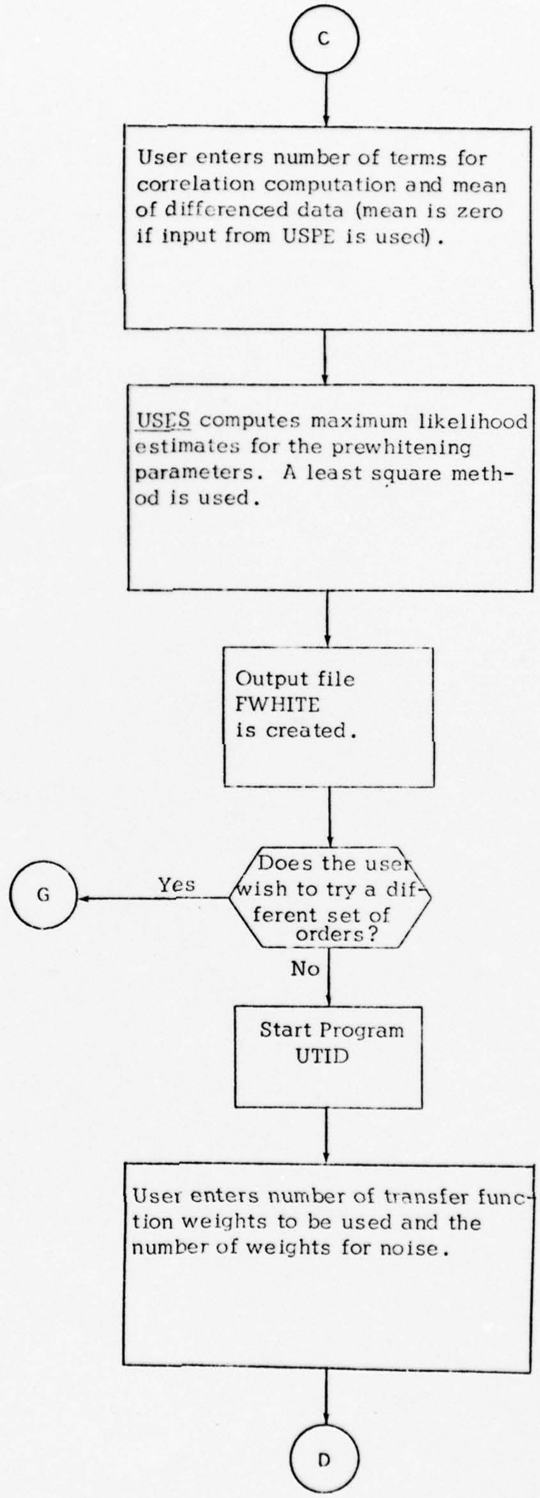
This has been a brief outline of how to use the six Box-Jenkins estimation programs. The curious -- and very hardy -- user can find out more about the inner workings of the programs by perusing the program listings which follow. There are listings for USID, USPE, USES, UTID, UTPE, UTES, and for MATINV, a matrix inversion program used in USPE, USES, UTPE and UTES.

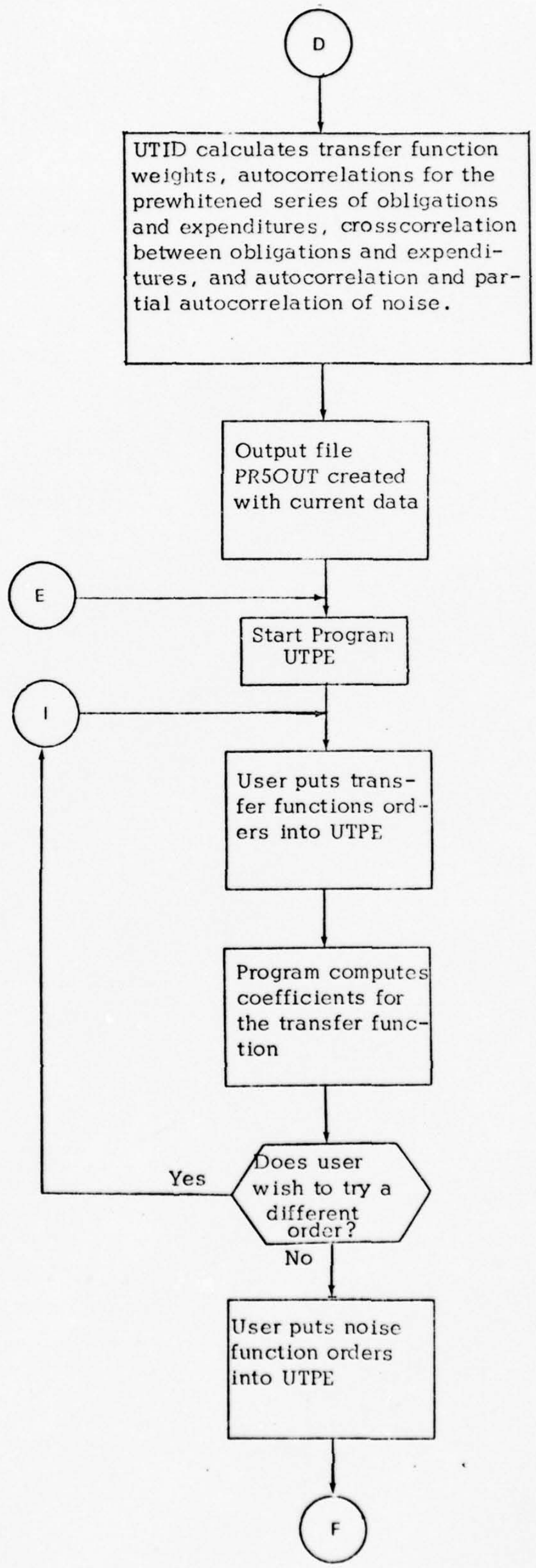
Flow Diagram of Box and Jenkins Analysis Programs

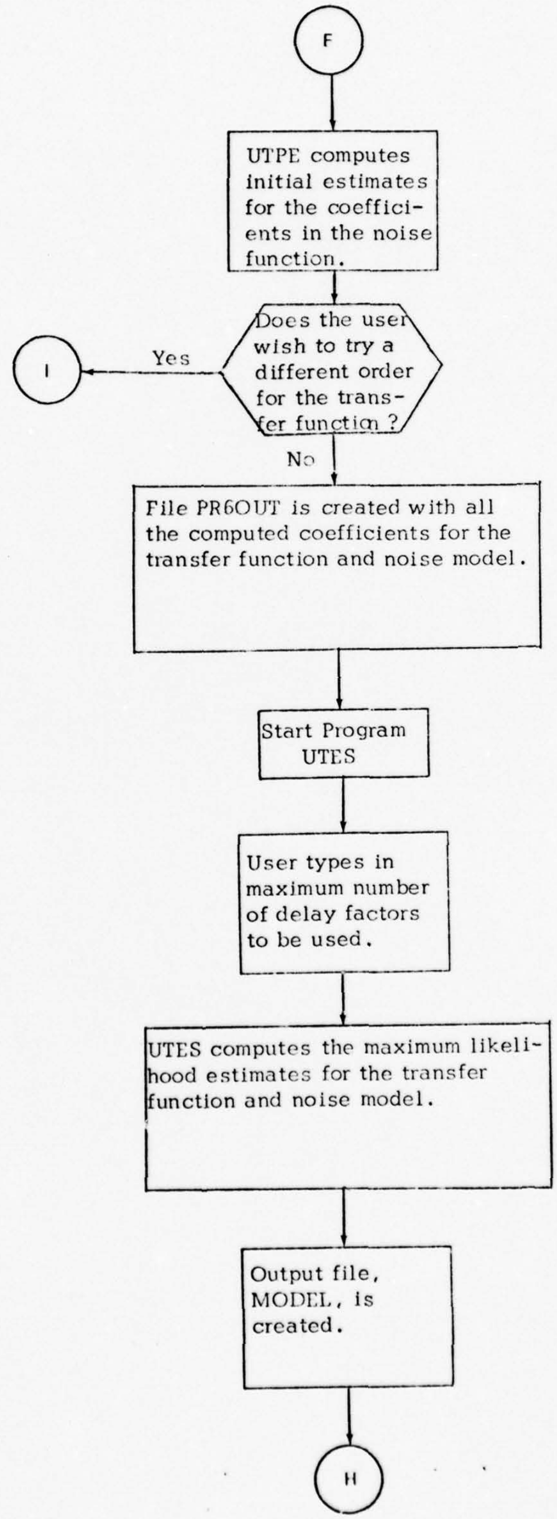
Figure E-1

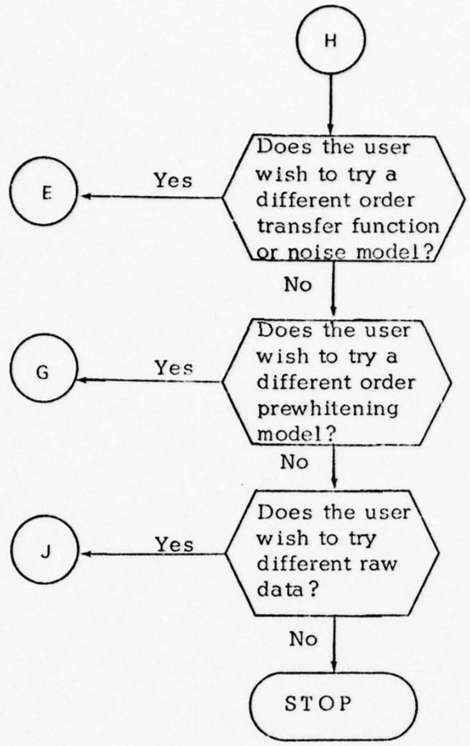



A
B
User puts prewhitening orders into USPE. (The order of a function expresses the number of terms of a given series that are to be used.) In this case the orders are for the number of terms of planned obligations to be used.
User also types in degree of accuracy desired and the maximum number of iterations to be used.
Program USPE computes covariance and estimates for the two sets of coefficients for the terms of the planned obligations. (The orders given above determine the number of coefficients estimated.)
Does the user want to change inputs?
Yes
B
No
Output file IWHITE is created
Start Program USES
C


C
User enters number of terms for correlation computation and mean of differenced data (mean is zero if input from USPE is used).
USES computes maximum likelihood estimates for the prewhitening parameters. A least square method is used.
Output file FWHITE is created.
Does the user wish to try a different set of orders?
Yes
G
No
Start Program UTID
User enters number of transfer function weights to be used and the number of weights for noise.
D

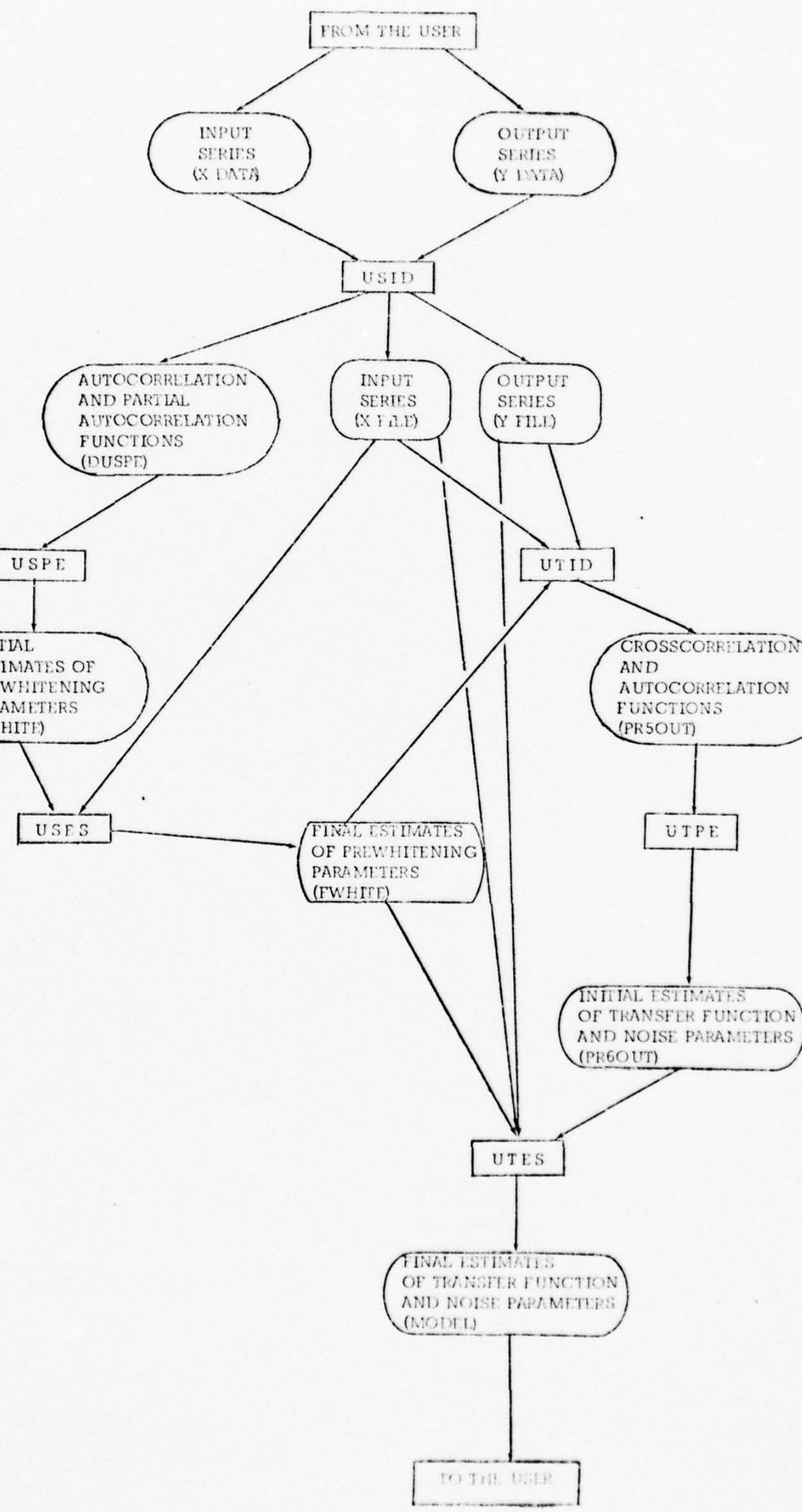

D
UTID calculates transfer function weights, autocorrelations for the prewhitened series of obligations and expenditures, crosscorrelation between obligations and expenditures, and autocorrelation and partial autocorrelation of noise.
Output file PR5OUT created with current data
E
Start Program UTPE
I
User puts transfer functions orders into UTPE
Program computes coefficients for the transfer function
Yes
Does user wish to try a different order?
No
User puts noise function orders into UTPE
F


F
UTPE computes initial estimates for the coefficients in the noise function.
Does the user wish to try a different order for the transfer function ?
Yes
I
No
File PR6OUT is created with all the computed coefficients for the transfer function and noise model.
Start Program UTES
User types in maximum number of delay factors to be used.
UTES computes the maximum likelihood estimates for the transfer function and noise model.
Output file, MODEL, is created.
H


H
Does the user wish to try a different order transfer function or noise model?
Yes
E
No
Does the user wish to try a different order prewhitening model?
Yes
G
No
Does the user wish to try different raw data?
Yes
J
No
STOP

CREATION AND USE OF FILES IN THE SIX PROGRAMS

FIGURE E-2



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Program 1 - USID

```
 10 DIMENSION X(100),XX(100),PXX(100),CXX(100),PCOR(20,200),Y(100)
 20 CALL DEFINE (1,'XDATA,')
 30 CALL DEFINE (2,'XFILE,')
 40 CALL DEFINE (3,'DUSPE,')
 50 CALL DEFINE (4,'YDATA,')
 60 CALL DEFINE (5,'YFILE,')
 70 WRITE(9,1000)
 80 1000 FORMAT(' 1 OR 2 INPUT STREAMS?')
 90 READ(9,1001) IST
100 1001 FORMAT(I4)
110 WRITE (9,16)
120 16 FORMAT ('ENTER N,DIFF.,MAXCOR.',5X)
130 READ (9,25) N,JD,MAXM
140 25 FORMAT (3I3)
150 DO 15 I=1,N
160 READ (1,10) X(I)
170 IF (IST.EQ.2) READ(4,10) Y(I)
180 XX(I)=X(I)
190 10 FORMAT (F10.3)
200 15 CONTINUE
210 DO 35 I=1,100
220 CXX(I)=0
230 PXX(I)=0
240 35 CONTINUE
250 XM=0
260 IF (IST.EQ.2) YM=0
270 IF (JD) 200,200,210
280 210 DO 220 I=1,JD
290 N=N-1
300 DO 220 J=1,N
310 X(J)=X(J+1)-X(J)
320 IF (IST.EQ.2) Y(J)=Y(J+1)-Y(J)
330 220 CONTINUE
340 200 IF (JD-1) 211,212,213
350 211 WRITE (9,11)
360 11 FORMAT (/,4X,'I',5X,,'X(I)',/)
370 GOTO 214
380 212 WRITE (9,12)
390 12 FORMAT (/,4X,'I',4X,'1DX(I)',/)
400 GOTO 214
410 213 WRITE (9,13)
420 13 FORMAT (/,4X,'I',4X,'2DX(I)',/)
430 214 CONTINUE
440 DO 40 I=1,N
```

```
XM = XM + X(I)/N
IF (IST.EQ.2) YM=YM+Y(I)/N
WRITE (9,19) I,X(I)
19 FORMAT (2X,I3,3X,F6.2)
40 CONTINUE
DO 60 I=1,N
X(I)=X(I)-XM
IF (IST.EQ.2) Y(I)=Y(I)-YM
60 CONTINUE
WRITE (9,17) XM
17 FORMAT ('MEAN = ',F6.2)
DO 100 K=0,MAXM
LAG = N-K
DO 90 J=1,LAG
IJ=J+K
K1=K+1
CXX(K1)=CXX(K1)+X(J)*X(IJ)/N
90 CONTINUE
VAR=CXX(1)
RXX(K1)=CXX(K1)/VAR
100 CONTINUE
PCOR(1,1)=RXX(2)
DO 300 L=2,MAXM
SUM1=0
SUM2=0
L1=L-1
L2=L1-1
DO 310 J=1,L1
LJ=L1-J
IF (L1-J) 400,401,400
400 PCOR(L1,J)=PCOR(L2,J)-PCOR(L1,L1)*PCOR(L2,LJ)
401 LJ1=LJ+2
J1=J+1
SUM1=SUM1+PCOR(L1,J)*RXX(LJ1)
SUM2=SUM2+PCOR(L1,J)*RXX(J1)
310 CONTINUE
L0=L+1
PCOR(L,L)=(RXX(L0)-SUM1)/(1.-SUM2)
300 CONTINUE
WRITE (9,301)
301 FORMAT (/,3X,'K',5X,'CXX(K)',5X,'RXX(K)',4X,'PCOR(K)',
K=0
K1=K+1
WRITE (9,302) K,CXX(K1),RXX(K1)
302 FORMAT (2X,I3,2X,F7.2,5X,F6.2)
DO 320 K=1,MAXM
K1=K+1
WRITE(9,303) K,CXX(K1),RXX(K1),PCOR(K,K)
303 FORMAT (2X,I3,2X,F7.2,5X,F6.2,5X,F6.2)
320 CONTINUE
WRITE(9,500)
```

USID (Cont'd)

```
500 FORMAT ('CREATE OUTPUT FILES WITH CURRENT SERIES? YES=1,NO=0.')
READ (9,501) IX
501 FORMAT (I4)
IF (IX.EQ.0) GOTO 600
WRITE(2,101) N
IF (IST.EQ.2) WRITE(5,101) N
101 FORMAT(I4)
WRITE (2,502) (X(J),J=1,N)
IF (IST.EQ.2) WRITE(5,502)(Y(J),J=1,N)
502 FORMAT(F12.6)
REWIND 2
IF (IST.EQ.2) REWIND 5
CALL DSAVE (2,ISTAT)
IF (IST.EQ.2) CALL DSAVE(5,ISTAT)
L=MAXM +1
WRITE (3,101) MAXM
WRITE(3,504) (CXX(I),I=1,L),XM
504 FORMAT (F12.6)
REWIND 3
CALL DSAVE (3,ISTAT)
600 STOP
END
```

Program 2 - USPE

```
DIMENSION KMA(10),A(10,10),PHI(10),CPR(30),COV(30),TAU(10),T1(10,
DIMENSION T2(10,10),T(10,10),F(10),H(10),THETA(10)
CALL DEFINE (1,'DUSPE,')
CALL DEFINE (2,'IWHITE,')
WRITE (9,10)
10 FORMAT('ENTER  P, Q,EPSILON,AND MAXITER.')
READ (9,11) IP,IQ,EPSLON,ITMAX
11 FORMAT(2I4,F10.4,I4)
READ (1,901) IK
901 FORMAT (I4)
DO 20 I=0,IK
I1=I+1
READ (1,12) COV(I1)
12 FORMAT (F12.6)
20 CONTINUE
READ (1,12) WBAR
* WBAR = MEAN OF W SERIES.
* COV(K) = K-1 ST AUTOCOVARIANCE OF W SEQUENCE.
* IP = NUMBER OF AUTOREGRESSIVE PARAMETERS.
* IQ = NUMBER OF MOVING AVERAGE PARAMETERS.
* IK = NUMBER OF COVARIANCE LAGS.
50 DO 1452 I=1,10
PHI(I) = 0.
THETA(I) = 0.
1452 CONTINUE
IF (IP.EQ.0) GOTO 300
DO 100 I=1,IP
DO 110 J=1,IP
IC=IABS(IQ+I-J)+1
A(I,J)=COV(IC)
110 CONTINUE
J1=J+1
IA=IQ+I+1
A(I,J1)=COV(IA)
100 CONTINUE
IP1=-(IP+1)
CALL MATINV(ISOL,IDSOL,IP,IP1,A,10,KWA,DET)
ITER=0
IF (ISOL-2) 120,121,122
121 WRITE (9,124) ISOL
124 FORMAT('ISOL =',I3,2X,'UNABLE TO SOLVE FOR PHI.')
GOTO 500
122 WRITE (9,123) ISOL
123 FORMAT('ISOL =',I3,2X,'INPUT ERROR FOR PHI SOLUTION.')
GOTO 500
```

USPE (Cont'd)

```
120 IF (IDSOL.EQ.1) GOTO 130
WRITE (9,125)
125 FORMAT('PHI DETERMINANT CALCULATION OVERFLOW.')
GOTO 500
130 ICOL=IP+1
PHI(1)=-1.0
DO 135 I=1,IP
I1=I+1
PHI(I1)=A(I,ICOL)
135 CONTINUE
IF(IQ .EQ. 0) GO TO 711
DO 200 J=0,IQ
SUM=0
DO 210 I=0,IP
DO 210 K=0,IP
IJK=IABS(J+I-K)+1
I1=I+1
K1=K+1
SUM=SUM+PHI(I1)*PHI(K1)*COV(IJK)
210 CONTINUE
J1=J+1
CPR(J1)=SUM
200 CONTINUE
GOTO 350
300 DO 310 J=0,IQ
J1=J+1
CPR(J1)=COV(J1)
310 CONTINUE
350 TAU(1)=CPR(1)**.5
DO 400 I=1,IQ
I1=I+1
TAU(I1)=0
400 CONTINUE
ITER = 1
650 DO 410 I=0,IQ
DO 410 J=0,IQ
I1=I+1
J1=J+1
T1(I1,J1)=0
T2(I1,J1)=0
410 CONTINUE
DO 420 I=0,IQ
IJ=IQ-I
DO 420 J=0,IJ
JP=I+1+J
J1=J+1
I1=I+1
T1(I1,J1)=TAU(JP)
T2(I1,JP)=TAU(J1)
420 CONTINUE
IQ1=IQ+1
```

```
DO 430 I=1,IQ1
DO 430 J=1,IQ1
T(I,J)=T1(I,J)+T2(I,J)
430 CONTINUE
DO 440 J=0,IQ
J1=J+1
IQ2=IQ-J
F(J1)=-CPR(J1)
DO 440 I=0,IQ2
I1=I+1
IJ=I1+J
F(J1)=F(J1)+TAU(I1)*TAU(IJ)
440 CONTINUE
IQ2=IQ+2
DO 450 J=0,IQ
J1=J+1
T(J1,IQ2)=F(J1)
450 CONTINUE
IQ2=-IQ2
CALL MATINV(ISOL,IDSOL,IQ1,IQ2,T,10,KWA,DET)
IFLAG=1
IF (ISOL-2) 460,461,462
461 WRITE(9,463) ISOL
463 FORMAT('ISOL=',I3,2X,'UNABLE TO SOLVE FOR H.')
GOTO 500
462 WRITE(9,464) ISOL
464 FORMAT('ISOL=',I3,2X,'INPUT ERROR FOR H SOLUTION.')
GOTO 500
460 IF (IDSOL.EQ.1) GOTO 600
WRITE(9,465)
465 FORMAT('H DETERMINANT CALCULATION OVERFLOW.')
GOTO 500
600 IQ2=IQ+2
DO 610 I=0,IQ
I1=I+1
H(I1)=T(I1,IQ2)
TAU(I1)=TAU(I1)-H(I1)
610 CONTINUE
DO 620 I=0,IQ
I1=I+1
FABS=ABS(F(I1))
IF (FABS.GE.EPSLON) GOTO 630
620 CONTINUE
GO TO 700
630 IF (ITER.GE.ITMAX) GOTO 640
ITER =ITER+1
GOTO 650
640 WRITE(9,641)
641 FORMAT('MAXIMUM ITERATIONS FOR TAU EXCEEDED.')
GOTO 500
700 DO 710 J=1,IQ
```

```
J1=I+1
THETA(J1)=-TAU(J1)/TAU(1)
710 CONTINUE
711 IF (IP.GT.0) GOTO 720
THETA(1)=WBAR
GOTO 730
720 SUM=0
DO 740 I=1,IP
I1=I+1
SUM=SUM+PHI(I1)
740 CONTINUE
THETA(1)=WBAR*(1.0-SUM)
730 IF (IQ.GT.0) GOTO 750
SUM=0
DO 760 I=1,IP
I1=I+1
SUM=SUM+PHI(I1)*COV(I1)
760 CONTINUE
SIGMA2=COV(1)-SUM
GOTO 770
750 SIGMA2=TAU(1)*TAU(1)
770 WRITE (9,771) IP,IQ,WBAR,SIGMA2
771 FORMAT(/,5X,'P=',I3,4X,'Q=',I3,4X,'WBAR=',F10.3,4X,'VAR AT=',F10.
WRITE(9,772)
772 FORMAT(/,4X,'I',5X,'COV(I)',3X,'PHI(I)',2X,'THETA(I)',/)
DO 780 I=0,IK
I1=I+1
IF (I.EQ.0) GOTO 775
IF (IP.GE.I) GOTO 781
IF (IQ.GE.I) GOTO 783
775 WRITE (9,790) I,COV(I1)
790 FORMAT(3X,I2,2X,F8.3)
GOTO 780
781 IF (IQ.GE.I) GOTO 785
WRITE (9,791) I,COV(I1),PHI(I1)
791 FORMAT(3X,I2,2X,F8.3,2X,F8.3)
GOTO 780
785 WRITE (9,792) I,COV(I1),PHI(I1),THETA(I1)
792 FORMAT(3X,I2,2X,F8.3,2X,F8.3,2X,F8.3)
GOTO 780
783 WRITE (9,793) I,COV(I1),THETA(I1)
793 FORMAT(3X,I2,2X,F8.3,12X,F8.3)
780 CONTINUE
GOTO 800
500 WRITE (9,501)
501 FORMAT('CHANGE INPUTS? YES-1,NO-CR.')
810 READ (9,502) IX
502 FORMAT(I2)
IF (IX.EQ.0) GOTO 900
WRITE (9,503) IK
503 FORMAT(/,'ENTER NEW P AND Q. P+Q.LE.',I3,'.',5X)
READ (9,504) IP,IQ
```

USPE (Cont'd)

```
504 FORMAT(2I3)
WRITE(9,506)
506 FORMAT('ENTER NEW MAXITER,EPSILON. NO CHANGE- CR.',5X)
READ (9,507) IX,DELTA
507 FORMAT(I5,F10.6)
IF (IX.EQ.0) GOTO 50
EPSLON=DELTA
ITMAX=IX
GOTO 50
800 WRITE(9,850)
850 FORMAT('CREATE INWHITE FILE? YES-1, NO-CR',5X)
READ(9,502) IXX
IF (IXX.EQ.0) GOTO 860
WRITE(2,851) IP,IQ
851 FORMAT(I4,/,I4)
IF (IP.EQ.0) GOTO 870
IP1=IP+1
WRITE(2,852)(PHI(I),I=2,IP1)
852 FORMAT(F12.6)
870 IF (IQ.EQ.0) GOTO 880
IQ1=IQ+1
WRITE(2,852)(THETA(I),I=2,IQ1)
880 REWIND 2
CALL DSAVE(2,ISTAT)
GOTO 900
860 WRITE(9,801)
801 FORMAT('CHANGE INPUTS? YES-1,NO-CR.',5X)
GOTO 810
900 STOP
END
```

Program 3 - USES

```
*                              MAIN ROUTINE
*BOX-JENKINS PROGRAM #3: UNIVARIATE STOCHASTIC MODEL ESTIMATION
*                                         (USES)
*'USES' TAKES THE TIME SERIES DATA, THE PROPOSED MODEL, AND THE
*INITIAL ESTIMATES OF THE PARAMETERS AND PRODUCES APPROXIMATE
*MAXIMUM LIKELIHOOD ESTIMATORS
*  LIST OF GLOBAL VARIABLES
* Z - TIMES SERIES DATA
* N - LENGTH OF SERIES
* W - EQUIVALENCED TO Z
* NRESID - LENGTH OF DIFFERENCED SERIES + FORECASTS
* RESID - RESIDUALS FROM NON-LINEAR LEAST SQUARES
* SUMSQ - SUM OF SQUARES OF RESID
* AINV - MATRIX USED IN CALCULATING COVMAT
* NBETA - NUMBER OF PARAMETERS
* P - NUMBER OF AUTOREGRESSIVE PARAMETERS
* Q - NUMBER OF MOVING AVERAGE PARAMETERS
* PS - NUMBER OF SEASONAL AR PARAMETERS
* QS - NUMBER OF SEASONAL MA PARAMETERS
* S - PERIOD OF SEASONAL EFFECT
* M - INDICATOR FOR PRECENCS OF CONSTANT TERM
* K - NUMBER OF AUTOCORRELATION LAGS
* MU - MEAN OF DIFFERENCED DATA
* PHI - AUTOREGRESSIVE PARAMETERS
* THETA - MOVING AVERAGE PARAMETERS
* PHIS - SEASONAL AR PARAMETERS
* THETAS - SEASONAL MA PARAMETERS
* COVMAT - COVARIANCE MATRIX FOR PARAMETER ESTIMATES
* STDDEV - STANDARD ERRORS FOR PARAMETER ESTIMATES
* R - CORRELATION MATRIX FOR PARAMETER ESTIMATES
* RAA - AUTOCORRLEATION FUNCTION FOR RESIDUALS
* CHISQ - CHISQUARE STATISTIC: SUM OF SQUARES OF RAA
* DF - DEGREES OF FREEDOM FOR CHISQ
* VAROFA - VARIANCE OF RESIDUALS
* THETA0 - CONSTANT TERM
        COMMON/PARAM1/P,Q,PS,QS,S,M,K
 +               /PARAM2/MU,PHI,THETA,PHIS,THETAS
 +                /SERIES/N,BETA
 +             /STAT/COVMAT,STDDEV,R,RAA,CHISQ,DF,VAROFA,THETA0
        INTEGER N,NRESID,NBETA,
 +                P,Q,PS,QS,S,J,K,DF
        REAL Z,W,RESID,SUMSQ,AINV,BETA,
 +            MU,PHI,THETA,PHIS,THETAS,
 +            COVMAT,STDDEV,R,RAA,CHISQ,VAROFA,THETA0
```

USES (Cont'd)

```
        DIMENSION Z(50),W(65),RESID(65),AINV(10,10),BETA(10),
     +            PHI(10),THETA(10),PHIS(10),THETAS(10),
     +            COVMAT(10,10),STDDEV(10),R(10,10),RAN(30)
        EQUIVALENCE (Z(1),W(1))
*
* 'INPUTS' READS DATA AND PARAMETERS ACCORDING TO USER OPTIONS
        CALL INPUTS(N)
*'LSQEST' GENERATES LEAST SQUARES ESTIMATES FOR THE PARAMETERS
*(AND CALCULATES RESID,SUMSQ,AINV)
        CALL LSQEST(NRESID,N,RESID,SUMSQ,AINV,NBETA)
*'STATS' PRODUCES SUMMARY STATISTICS ON THE ESTIMATES AND RESUDUAL
        CALL STATS(NBETA,NRESID,N,RESID,SUMSQ,AINV)
*OUTPTS' PRINTS THE RESIDUALS AND STATISTICS PRODUCED ABOVE
        CALL OUTPTS(N,NRESID,RESID,NBETA)
       STOP
        END
*THIS IS A PROGRAM TO READ INPUT FOR MODEL PARAMETER ESTIMATION
*
        SUBROUTINE INPUTS(N)
*
        COMMON/PARAM1/P,Q,PS,QS,S,M,K
     +        /PARAM2/WBAR,PHI,THETA,PHIS,THETAS
     +        /SERIES/Z
        INTEGER P,Q,PS,QS,S,M,K,SEASON,I
        REAL PHI,THETA,PHIS,THETAS,Z
        DIMENSION PHI(10),THETA(10),PHIS(10),THETAS(10),Z(50)
        CALL DEFINE(1,'IWHITE,')
        CALL DEFINE(2,'XFILE,')
*                       GET SERIES DATA
        READ(2,200)N
 200    FORMAT(I4)
        WRITE(9,250)
  250   FORMAT(31H HOW MANY AUTOCORRELATION LAGS?)
        READ(9,200) K
        READ(2,300)(Z(I),I=1,N)
  300   FORMAT(F12.6)
*                       GET MODEL PARAMETERS
        WRITE(9,350)
   350  FORMAT(34H WHAT IS MEAN OF DIFFERENCED DATA?)
        READ(9,300) WBAR
        IF (WBAR.EQ.0) M=0
        IF (WBAR.NE.0) M=1
        DO 21 I=1,10
        PHI(I)=0.
        THETA(I)=0.
        PHIS(I)=0.
        THETAS(I)=0.
 21     CONTINUE
        READ(1,400) P,Q
 400    FORMAT(I4,/,I4)
        WRITE(9,500)
```

```
500 FORMAT(37H IS SEASONALITY PRESENT? (NO=0,YES=1))
    READ(9,200) SEASON
    IF (SEASON.EQ.1) GOTO 30
    PS=0
    QS=0
    S=0
    DS=0
    GOTO 40
 30 READ(1,600) PS,QS,S
600 FORMAT(3(I4,/))
 40 IF (P.NE.0) READ(1,700)(PHI(I),I=1,P)
    IF (Q.NE.0) READ(1,700)(THETA(I),I=1,Q)
    IF (PS.NE.0) READ(1,700)(PHIS(I),I=1,PS)
    IF (QS.NE.0) READ(1,700)(THETAS(I),I=1,QS)
700 FORMAT(F12.6)
     RETURN
     END
*THIS IS A PROGRAM TO FIND THE LEAST SQUARES ESTIMATES FOR MODEL
*PARAMETERS
*
    SUBROUTINE LSQEST(NRESID,NN,RESID,SUMSQ,AINV,NBETA)
*
    COMMON/PARAM1/P,Q,PS,QS,DUMMY1,M
+         /PARAM2/MU,PHI,THETA,PHIS,THETAS
+         /SERIES/W,BETA
    INTEGER P,Q,PS,QS,M,NBETA,NRESID,I,DUMMY1,
+         N,NP,NQ,NPS
    REAL MU,PHI,THETA,PHIS,THETAS,W,BETA,RESID,SUMSQ,AINV
    DIMENSION PHI(10),THETA(10),PHIS(10),THETAS(10),RESID(65),
+             W(65),AINV(10,10),BETA(10),WORK1(65),WORK2(10)
    NBETA=M+P+Q+PS+QS
    IF (NBETA.NE.0) GOTO 10
*       IF NO PARAMETERS, DO NO ESTIMATION
    NRESID=NN
    SUMSQ=0.
    DO 1 I=1,NN
    RESID(I)=W(I)
    SUMSQ=SUMSQ+RESID(I)*RESID(I)
  1 CONTINUE
    GOTO 100
 10 NP=M+P
    NQ=NP+Q
    NPS=NQ+PS
*          MAKE UP BETA VECTOR FOR SUBROUTINE
    IF (M.EQ.1) BETA(1)=MU
    IF (P.EQ.0) GOTO 20
    DO 11 I=1,P
    N=M+I
    BETA(N)=PHI(I)
 11 CONTINUE
```

```
 20  IF (Q.EQ.0) GOTO 30
     DO 21 I=1,Q
     H=HP+1
     BETA(H)=THETA(I)
 21  CONTINUE
 30  IF (PS.EQ.0) GOTO 40
     DO 31 I=1,PS
     H=HQ+1
     BETA(H)=PHIS(I)
 31  CONTINUE
 40  IF (QS.EQ.0) GOTO 50
     DO 41 I=1,QS
     H=HPS+1
     BETA(H)=THETAS(I)
 41  CONTINUE
 50  CALL MARQUA(NN,NBETA,NBETA+1,NRESID,.01,.00001,.1,100.,.001,
+                  WORK1,WORK2,AINV,RESID,SUMSQ)
*              REPLACE ORIGINAL ESTIMATES WITH LEAST SQUARES ESTIMATES
     IF (M.EQ.1) MU=BETA(1)
 60  IF (P.EQ.0) GOTO 70
     DO 61 I=1,P
     H=M+I
     PHI(I)=BETA(H)
 61  CONTINUE
 70  IF (Q.EQ.0) GOTO 80
     DO 71 I=1,Q
     H=HP+I
     THETA(I)=BETA(H)
 71  CONTINUE
 80  IF (PS.EQ.0) GOTO 90
     DO 81 I=1,PS
     H=HQ+I
     PHIS(I)=BETA(H)
 81  CONTINUE
 90  IF (QS.EQ.0) GOTO 100
     DO 91 I=1,QS
     H=HPS+I
     THETAS(I)=BETA(H)
 91  CONTINUE
*              PUT OUT FILE OF FINAL ESTIMATES
 100 CALL DEFINE(3,'FNWHITE,')
     WRITE(3,300) P,Q
 300 FORMAT(I4,/,I4)
     IF (NBETA.NE.0) WRITE(3,200)(BETA(I),I=1,NBETA)
 200 FORMAT(F12.6)
     RETURN
     END
*THIS IS A PROGRAM TO CALCULATE SUMMARY STATISTICS RELATING TO
*MODEL ESTIMATION
*
     SUBROUTINE STATS(NBETA,NRESID,NN,A,SUMSQ,AINV)
```

USES (Cont'd)

```
*
      COMMON/PARAM1/P,Q,PS,QS,S,M,K
     +      /PARAM2/MU,PHI,THETA,PHIS,THETAS
     +      /STAT/COVMAT,STDDEV,R,RAA,CHISQ,DF,VAROFA,THETA0
      INTEGER NN,NBETA,NRESID,P,Q,PS,QS,S,M,K,DF,I,J,MAX,N,A1
      REAL PHI,PHIS,THETA,THETAS,MU,A,VAROFA,COVMAT,STDDEV,R,THETA0
     +    RAA,CHISQ,G1,G2,ABAR,ASQ,CAA0,CAA,SUMSQ,AINV
      DIMENSION PHI(10),THETA(10),PHIS(10),THETAS(10),A(NRESID),
     +          COVMAT(10,10),STDDEV(10),R(10,10),CAA(30),RAA(30)
     +          ,AINV(10,10)
      EQUIVALENCE (CAA(1),RAA(1))
*
*                    RESIDUAL VARIANCE
      VAROFA=SUMSQ/(NN-P-Q-PS-QS-N)
*                    COVARIANCE MATRIX FOR ESTIMATES
   10 DO 11 I=1,NBETA
      DO 12 J=1,NBETA
      COVMAT(I,J)=AINV(I,J)*VAROFA
   12 CONTINUE
*                    STANDARD ERRORS
      STDDEV(I)=SQRT(COVMAT(I,I))
   11 CONTINUE
*                    CORRELATION MATRIX FOR ESTIMATES
   20 DO 21 I=1,NBETA
      DO 22 J=1,NBETA
      IF (COVMAT(I,J).NE.0.) R(I,J)=COVMAT(I,J)/(STDDEV(I)*STDDEV(J
      IF (COVMAT(I,J).EQ.0.) R(I,J)=0.
   22 CONTINUE
   21 CONTINUE
*                     CONSTANT TERM IN MODEL
   30 G1=1.
      IF (P.EQ.0) GOTO 40
      DO 31 I=1,P
      G1=G1-PHI(I)
   31 CONTINUE
   40 G2=1.
      IF (PS.EQ.0) GOTO 50
      DO 41 I=1,PS
      G2=G2-PHIS(I)
   41 CONTINUE
   50 THETA0=MU*G1*G2
*                     RESIDUAL AUTOCORRELATION FUNCTION
      ABAR=0.
      ASQ=0.
      A1=NRESID-NN+1
      DO 51 I=A1,NRESID
      ABAR=ABAR+A(I)
      ASQ=ASQ+A(I)*A(I)
   51 CONTINUE
      ABAR=ABAR/NN
      CAA0=ASQ/NN-ABAR*ABAR
      CHISQ=0.
```

USES (Cont'd)

```
      DO 52 I=1,K
      MAX=NRESID-I
      CAA(I)=0.
      DO 53 J=A1,MAX
      H=J+I
      CAA(I)=(A(J)-ABAR)*(A(H)-ABAR)+CAA(I)
 53   CONTINUE
      RAA(I)=CAA(I)/NN/CAA0
*                        CHI-SQUARE STATISTIC
      CHISQ=CHISQ+RAA(I)*RAA(I)
 52   CONTINUE
      CHISQ=NN*CHISQ
*                        NUMBER OF D.F. FOR CHI-SQUARE
      DF=K-M-P-Q-PS-QS
      RETURN
      END
*THIS IS A PROGRAM TO PRINT OUT RESULTS OF ESTIMATION
*
      SUBROUTINE OUTPT3(NN,NRESID,RESID,NBETA)
*
       COMMON/PARAM1/DUMMY(6),K
+      /STAT/COVMAT,STDDEV, R,RAA,CHISQ,DF,VAROFA,THETA0
       INTEGER DF,NRESID,NBETA,K,DUMMY,NN,START
      REAL RESID,COVMAT,STDDEV,R,RAA,CHISQ,VAROFA,THETA0
      DIMENSION RESID(NRESID),COVMAT(10,10),STDDEV(10),R(10,10),
+               RAA(30)
*                      ESTIMATES
      WRITE(9,300)
 300  FORMAT(31H COVARIANCE MATRIX OF ESTIMATES)
      CALL MATOUT(NBETA,1)
      WRITE(9,400)
 400  FORMAT(33H STANDARD DEVIATIONS OF ESTIMATES)
      DO 41 I=1,NBETA
      WRITE(9,110) STDDEV(I)
 41   CONTINUE
      WRITE(9,500)
 500  FORMAT(32H CORRELATION MATRIX OF ESTIMATES)
      CALL MATOUT(NBETA,2)
      WRITE(9,600) THETA0
 600  FORMAT(16H CONSTANT TERM:  ,F8.3)
*                      RESIDUALS
      START=NRESID-NN+1
      WRITE(9,100)
100   FORMAT(38H RESIDUALS FOR LEAST SQUARES ESTIMATES)
      DO 11 I=START,NRESID
      WRITE(9,110) RESID(I)
 11   CONTINUE
 110  FORMAT(F8.3)
      WRITE(9,200) VAROFA
 200  FORMAT(20H RESIDUAL VARIANCE:  ,F8.3)
      WRITE(9,700)
 700  FORMAT(26H RESIDUAL AUTOCORRELATIONS)
```

```
      DO 71 I=1,K
      WRITE (9,110) RAA(I)
 71   CONTINUE
      WRITE(9,800) CHISQ,DF
 800  FORMAT(23H CHI-SQUARE STATISTIC: ,F8.3,2H (,I4,6H D.F.))
      RETURN
      END
*THIS IS A SUBPROGRAM TO PRINT A SQUARE MATRIX IN SEMI-NICE FORM
*
      SUBROUTINE MATOUT(DIM,SWITCH)
*
      COMMON /STAT/COVMAT,DUMMY(10),R
      INTEGER DIM,SWITCH,I,J,MIN,MAX
      REAL COVMAT,R,MATRIX
      DIMENSION COVMAT(10,10),R(10,10),MATRIX(10,10)
      IF (SWITCH.EQ.2) GOTO 20
*                       TO PRINT COVARIANCE MATRIX
 10   DO 11 I=1,DIM
      DO 1 J=1,DIM
      MATRIX(I,J)=COVMAT(I,J)
 1    CONTINUE
 11   CONTINUE
      GOTO 30
 20   DO 21 I=1,DIM
      DO 2 J=1,DIM
      MATRIX(I,J)=R(I,J)
 2    CONTINUE
 21   CONTINUE
 30   IF (DIM.GT.7) GOTO 40
*                       IF 1 ROW WILL FIT ON 1 LINE
      DO 35 I=1,DIM
      WRITE(9,100) (MATRIX(I,J),J=1,DIM)
 35   CONTINUE
 100  FORMAT(7F8.3)
      RETURN
*                       IF 1 ROW WILL NOT  FIT ON 1 LINE
 40   DO 41 I=1,DIM
      WRITE(9,200) (MATRIX(I,J),J=1,7)
 200  FORMAT(7F8.3)
      MIN=1
      MAX=7
 50   MIN=MIN+7
      MAX=MAX+7
      IF (MAX.GE.DIM) GOTO 60
      WRITE(9,300) (MATRIX(I,J),J=MIN,MAX)
 300  FORMAT(2X,7F8.3)
      GOTO 50
 60   WRITE(9,300) (MATRIX(I,J),J=MIN,DIM)
 41   CONTINUE
      RETURN
      END
```

```
      ******************    MARQUA    ********************************
*
      SUBROUTINE MARQUA (NN,NBETA,NBETA1,NRES,PIE,EPS,F2,UBP1,DELTA,
     +  RESIDS,  KNA,ALPHA,AT,SBO)
      COMMON /PARAM1/P,Q,PS,QS,S,DUM,MY,M
     +      /SERIES/ W(65), BETAO(10)
      INTEGER P,Q,PS,QS,S,M,DUM,MY
      DIMENSION  BETA (10),  X (10, 65), D(10), KNA(NBETA),  ALPHA(10,10
     +     ,AT(NRES), RESIDS(NRES), A(10,11)
      .WRITE (9,10) NBETA
      CALL CRESID (NN,NBETA,NRES,AT,SBO)
      WRITE(9,300)  (BETAO(IX) ,IX=1,NBETA)
      WRITE (9,302) SBO
   10 FORMAT (7H NBETA ,2I5)
****   CALCULATION OF DERIVATIVES  ...
 90  DO 80 II = 1,10
     DO 81 JJ = 1,11
     A(II,JJ) = 0.0
 81 CONTINUE
 80  CONTINUE
    DO 100 II = 1,NBETA
      BTEMP = BETAO(II)
      BETAO(II) = BTEMP + DELTA
      CALL CRESID (NN,NBETA,NRES,RESIDS,SBOS)
    .WRITE (9,300) (BETAO (IX) ,IX=1,NBETA)
     .WRITE (9,302)  SBOS
      BETAO(II) = BTEMP
      DO 110 IT = 1, NRES
      X(II,IT) = ( AT(IT) - RESIDS(IT) ) / DELTA
 110 CONTINUE
 100 CONTINUE
     .WRITE (9,901)  ((X(II,IT),IT=1,NRES),II=1,NBETA)
 300 FORMAT (/,9H BETAS   , 3(/ 5F8.4))
  120 DO 130 II = 1,NBETA
      DO 140 JJ = 1,NBETA
      DO 150 IT = 1,NRES
     A(II,JJ) = A(II,JJ) + X(II,IT) * X(JJ,IT)
* CALCULATION OF VARIABLE G
        IF (II.EQ.1) A(JJ,NBETA1) = A(JJ,NBETA1) + X(JJ,IT) * AT(IT)
 150 CONTINUE
     ALPHA(II,JJ) = A(II,JJ)
 140 CONTINUE
 130 CONTINUE
     CALL MATINV (ISOL,IDSOL,NBETA,NBETA,ALPHA,10,KNA,DET)
     .WRITE (9,902) ((A(II,JJ),JJ=1,NBETA1),II=1,NBETA)
 901 FORMAT (/  9H X ARRAY , 5(/, 9(1X,F7.1)))
 902 FORMAT (/  9H A ARRAY , 5(/, 5(2X,F12.2)))
     DO 170 II = 1, NBETA
      D(II) =SQRT (A(II,II))
  900 FORMAT (3H D ,F10.2)
 170 CONTINUE
```

```
180 DO 190 II = 1, NBETA
     DO 200 JJ = 1, NBETA
     IF (II.EQ.JJ) GO TO 210
    A(II,JJ) = A(II,JJ) /(D(II) * D(JJ))
     GO TO 200
210 A(II,II) = 1. + PIE
200 CONTINUE
    *   CALCULATION OF 'G' VARIABLES  .
    A(II,NBETA1) = A(II,NBETA1) / D(II)
190 CONTINUE
    .WRITE (9,902) ((A(II,JJ),JJ = 1,NBETA1), II = 1,NBETA)
     CALL MATINV (ISOL,IDSOL,NBETA,NBETA1,A,10,KWA,DET)
220 FORMAT (/,16H MATINV  ISOL = ,I3,9H IDSOL = ,I5, 7H DET = ,F 16.
     DO 230 JJ = 1,NBETA
* CALCULATION OF ARRAY H
    A (JJ,NBETA1) = A (JJ,NBETA1) / D (JJ)
230 CONTINUE
    .WRITE (9,902) ((A(II,JJ),JJ=1,NBETA1),II=1,NBETA)
     DO 240 JJ = 1,NBETA
     BETA(JJ) = BETAO(JJ)
    BETAO(JJ) = BETAO (JJ) + A(JJ,NBETA1)
240 CONTINUE
    CALL CRESID (NW,NBETA,NRES,RESIDS,SB)
    WRITE (9,300) (BETAO (IX),IX=1,NBETA)
    WRITE (9,302) SB,SBO
     IF (SB.GT.SBO) GO TO 250
     DO 260 JJ = 1,NBETA
* TESTING 'H*'.......
    HSTAR = ABS(A(JJ,NBETA1))
     IF (HSTAR.GE.EPS) GO TO 270
260 CONTINUE
    DO 281 JJ = 1,NBETA
    BETAO(JJ) = BETA(JJ)
281 CONTINUE
     GO TO 290
270  PIE = PIE * F2
SBO=SB
    DO 275 JJ = 1,NRES
    AT(JJ) = RESIDS(JJ)
275 CONTINUE
     GO TO  90
250 PIE = PIE / F2
910 FORMAT (/ 23H PIE EPS F2 UBPI DELTA  ,/ 5F14.5)
    DO 280 JJ = 1,NBETA
    BETAO(JJ) = BETA(JJ)
280 CONTINUE
     IF (PIE.GT.UBPI)  GO TO 290
     GO TO 180
  290 WRITE (9,301) (BETAO(IX),IX=1,NBETA)
 301 FORMAT (/12H FINAL BETA ,/10F6.3)
     WRITE (9,302) SBO
```

```
 302 FORMAT (5H S30 ,2F11.3)
       RETURN
       END
     *************************
 SUBROUTINE TO DO ESTIMATION OF RESIDUALS
*
         SUBROUTINE CRESID(NN,NBETA,NRESID,RESID,SUMSQ)
*
       COMMON/PARAM1/P,Q,IDUMMY(3),M
+            /PARAM2/MU,PHI,THETA
+            /SERIES/N,BETA
       INTEGER P,Q
       REAL MU
       DIMENSION N(65),WNEG(50),RESID(65),RNEG(50),BETA(10),PHI(5),THETA(5
       IF (P.EQ.0) GOTO 30
       DO 1 J=1,P
       JM=J+M
       PHI(J)=BETA(JM)
  1    CONTINUE
 30    IF (Q.EQ.0) GOTO 40
       DO 2 J=1,Q
       JMP=J+M+P
       THETA(J)=BETA(JMP)
  2    CONTINUE
 40    IF (M.EQ.1) MU=BETA(1)
       CALL BKFCST(NN,RESID,WNEG,RNEG,INDEX,SUMSQ)
       ISHIFT=MIN0(15,1-INDEX)
       DO 10 I=1,NN
       J=NN+1-I
       JS=NN+1-I+ISHIFT
       RESID(JS)=RESID(J)
 10    CONTINUE
       DO 20 I=1,ISHIFT
       IS=ISHIFT+1-I
       RESID(IS)=RNEG(I)
 20    CONTINUE
       NRESID=NN+ISHIFT
      ,WRITE(9,200)(RESID(I),I=1,NRESID)
 200 FORMAT(65(/F10.3))
       RETURN
       END
SUBROUTINE BKFCST(N,RESID,WNEG,RNEG,INDEX,SBO)
COMMON/PARAM1/P,Q
+      /PARAM2/MU,PHI,THETA
+      /SERIES/N(65)
DIMENSION RESID(65),WNEG(50),RNEG(50),E(50),PHI(5),THETA(5)
REAL MU
INTEGER P,Q
999 FORMAT (5H PHI ,8H IN BACK,/1XF8.3)
DO 10 I=1,50
E(I)=0.
```

```
RESID(I)=0.
RNEG(I)=0.
WNEG(I)=MU
10 CONTINUE
SDD=0.
NP=N-P
DO 20 IDUM=1,NP
I=NP+1-IDUM
SUMP=0.
SUMT=0.
DO 30 J=1,P
IJ=I+J
SUMP=SUMP+PHI(J)*W(IJ)
30 CONTINUE
DO 40 K=1,Q
IK=I+K
IF (IK.GT.N) GOTO 40
SUMT=SUMT+THETA(K)*E(IK)
40 CONTINUE
E(I)=W(I)-SUMP+SUMT
998 FORMAT(3H E(,I3, 3H) =,F10.3)
20 CONTINUE
DO 50 IDUM=0,49
I=-IDUM
SUMP=0.
SUMT=0.
DO 60 J=1,P
IJ=I+J
IF (IJ.LE.0) GOTO 61
SUMP=SUMP+PHI(J)*W(IJ)
GOTO 60
61 IJ1=-(I+J)+1
SUMP=SUMP+PHI(J)*WNEG(IJ1)
60 CONTINUE
DO 70 K=1,Q
IK=I+K
IF (IK.LE.0) GOTO 70
SUMT=SUMT+THETA(K)*E(IK)
70 CONTINUE
I1=-I+1
WNEG(I1)=WNEG(I1)+SUMP-SUMT
.WRITE (9,997) I1,WNEG(I1)
997 FORMAT(6H WNEG(,I3, 3H) =,F10.3)
INDEX =1
WC=ABS(WNEG(I1)-MU)
IF (WC.LE..01) GOTO 100
50 CONTINUE
100 DO 110 I=INDEX,N
SUMP=0.
SUMT=0.
```

```
DO 120 J=1,P
IJ=I-J
IF (IJ.GT.0) GOTO 121
IF (IJ.LT.INDEX) GOTO 120
IJ1=-IJ+1
SUMP=SUMP+PHI(J)*WNEG(IJ1)
GOTO 120
121 SUMP=SUMP+PHI(J)*W(IJ)
120 CONTINUE
DO 130 K=1,Q
IK=I-K
IF (IK.GT.0) GOTO 131
IF (IK.LT.INDEX) GOTO 130
IK1=-IK+1
SUMT=SUMT+THETA(K)*RNEG(IK1)
GOTO 130
131 SUMT=SUMT+THETA(K)*RESID(IK)
130 CONTINUE
IF (I.LE.0) GOTO 140
RESID(I)=W(I)-SUMP+SUMT
.WRITE (9,996) I,RESID(I)
996 FORMAT(7H RESID(,I3, 3H( =,F10.3)
SBO=SBO+RESID(I)*RESID(I)
GOTO 110
140 I1=-I+1
RNEG(I1)=WNEG(I1)-SUMP+SUMT
.WRITE (9,995) I1,RNEG(I1)
995 FORMAT(6H RNEG(,I3,3H) =,F10.3)
SBO=SBO+RNEG(I1)*RNEG(I1)
110 CONTINUE
RETURN
END
```

Program 4 - UTID

```
10 REAL NOISE,NBAR
20 COMMON NH,ADUM(720)
30 COMMON /CC1/ NP,ALPHA(300),BETA(300),SA,SB,RAA(20),RBB(20),RAB(100)
40 COMMON /AC1/ NNG,NOISE(300),SN,RNN(20),PCOR(20)
50 DIMENSION X(300),Y(300),PHI(10),THETA(10),V(20)
60 CALL DEFINE (1,'XFILE;')
70 CALL DEFINE (2,'YFILE;')
80 CALL DEFINE (3,'PR5OUT;')
90 CALL DEFINE (4,'FWHITE;')
100 * N = NUMBER OF (X,Y) PAIRS.
110 * IP = NO. OF AUTOREGRESSIVE PARAMETERS.
120 * IQ = NO. OF MOVING AVERAGE PARAMETERS.
130 * NH = NO. OF TRANSFER FUNCTION WEIGHTS, V, TO BE ESTIMATED.
140 * NO = NO. OF TRANSFER FUNCTION WEIGHTS FOR GENERATING NOISE SERIES.
150 READ (4,11) IP,IQ
160 11 FORMAT (2I4)
170 READ(1,202) N
180 READ(2,202) NOTHER
190 202 FORMAT(I4)
200 IF(N .NE. NOTHER) GO TO 500
210 DO 20 I = 1,N
220 ALPHA(I) = 0.
230 BETA(I) = 0.
240 READ (1,21) X(I)
250 READ (2,21) Y(I)
260 21 FORMAT (F12.6)
270 20 CONTINUE
280 IF (IP.EQ.0) GOTO 39
290 READ(4,30)(PHI(I),I=1,IP)
300 30 FORMAT (F12.6)
310 39 IF (IQ.EQ.0) GOTO 50
320 READ(4,30)(THETA(I),I=1,IQ)
330 WRITE(9,64)
340 64 FORMAT('PREWHITENING PARAMETERS')
350 IF (IP.EQ.0) GOTO 61
360 WRITE(9,60)
370 60 FORMAT(4X,'I',5X,'PHI(I)')
380 DO 63 I=1,IP
390 WRITE(9,62) I,PHI(I)
400 62 FORMAT(I5,2X,F9.4)
410 63 CONTINUE
420 61 IF (IQ.EQ.0) GOTO 50
430 WRITE(9,65)
440 65 FORMAT(4X,'I',3X,'THETA(I)')
```

```
DO 66 I=1,10
WRITE(9,62) I,THETA(I)
66 CONTINUE
50 WRITE(9,51)
51 FORMAT ('ENTER NO.TRANSFER WGTS. AND NO. TO BE USED FOR NOISE.',2X)
READ (9,52) NH,NG
52 FORMAT (2I6)
NP=N-IP
IP1=IP+1
DO 100 IT=IP1,N
ITP=IT-IP
PSUMX=0
PSUMY=0
DO 110 I=1,IP
IXY=IT-I
PSUMX=PSUMX + PHI(I)*X(IXY)
PSUMY=PSUMY+PHI(I)*Y(IXY)
110 CONTINUE
QSUMX=0
QSUMY=0
DO 120 J=1,IQ
ITJ=IT-J-IP
IF (ITJ.LE.0) GOTO 120
QSUMX=QSUMX+THETA(J)*ALPHA(ITJ)
QSUMY=QSUMY+THETA(J)*BETA(ITJ)
120 CONTINUE
ALPHA(ITP)=X(IT)-PSUMX+QSUMX
BETA(ITP)=Y(IT)-PSUMY+QSUMY
100 CONTINUE
CALL CRSCOR
NH1=NH+1
DO 200 K=1,NH
K1=K+1
V(K1)=RAB(K)*SB/SA
200 CONTINUE
WRITE (9,210) SA,SB
210 FORMAT (5X,'S.D. ALPHA =',F10.4,5X,'S.D. BETA =',F10.4)
WRITE (9,220)
220 FORMAT(6X,'K',4X,'RAA(K)',4X,'RBB(K)',4X,'RAB(K)',4X,'RAB(-K)',6X,
+ 'V(K)',/)
V(1)=RAB(51)*SB/SA
R=1.0
DO 230 K=1,NH1
K1=K-1
KK=51+K1
IF (K.EQ.1) GOTO 235
WRITE (9,236) K1,RAA(K1),RBB(K1),RAB(K1),RAB(KK),V(K)
236 FORMAT(4X,I3,3F10.3,F11.3,F10.3)
GOTO 230
235 WRITE(9,237) K1,R,R,RAB(KK),V(K)
237 FORMAT(4X,I3,3F10.3,11X,F10.3)
230 CONTINUE.
```

```
MNG=N-NG
NG1=NG+1
DO 300 IT=NG1,N
SUM=0
DO 310 IG=1,NG1
ITG=IT-IG+1
SUM=SUM+V(IG)*X(ITG)
310 CONTINUE
NOISE(IT)=Y(IT)-SUM
300 CONTINUE
NBAR=0
DO 350 IT=NG1,N
ITG=IT-NG
NOISE(ITG)=NOISE(IT)
NBAR=NBAR + NOISE(ITG)/MNG
350 CONTINUE
CALL ACOR
WRITE (9,360) NBAR,SN
360 FORMAT(5X,'NOISE MEAN =',F8.4,3X,'S.D OF NOISE =',F8.4,/)
VARN=SN*SN
WRITE (9,365)
365 FORMAT(6X,'K',5X,'RNN(K)',3X'PCOR(K)')
DO 370 K=1,NH
WRITE(9,375) K,RNN(K),PCOR(K)
375 FORMAT(4X,I3,2F10.3)
370 CONTINUE
WRITE (9,400)
400 FORMAT('CHANGE TRANSFER WGT. VALUES? YES-1,NO-CR.',2X)
READ(9,401)IX
IF (IX.EQ.1) GOTO 50
WRITE (9,410)
410 FORMAT(/,'CREATE OUTPUT FILE WITH CURRENT DATA? YES-1,NO-CR.',2X)
READ (9,401) IX
401 FORMAT(I4)
IF (IX.EQ.0) GOTO 500
NH1=NH+1
WRITE(3,403) NH
403 FORMAT(I4)
WRITE(3,402) (V(I),I=1,NH1),(RNN(I),I=1,NH),VARN
REWIND 3
CALL DSAVE (3,ISTAT)
402 FORMAT(F12.6)
500 STOP
END
SUBROUTINE CRSCOR
COMMON MAIN,X(300),Y(300),ADUM(120)
COMMON /CC1/N,XX(300),YY(300),SDX,SDY,RXX(20),RYY(20),RXY(100)
DO 15 I=1,N
X(I)=XX(I)
Y(I)=YY(I)
15 CONTINUE
```

```
DO 35 I=1,100
IF (I.GT.20) GOTO 25
RXX(I)=0
RYY(I)=0
25 RXY(I)=0
35 CONTINUE
XM=0
YM=0
DO 40 I=1,N
XM=XM+X(I)/N
YM=YM+Y(I)/N
40 CONTINUE
DO 60 I=1,N
X(I)=X(I)-XM
Y(I)=Y(I)-YM
60 CONTINUE
VARX=0
VARY=0
DO 70 J=1,N
VARX=VARX+X(J)*X(J)/N
VARY=VARY+Y(J)*Y(J)/N
RXY(51)=RXY(51)+X(J)*Y(J)/N
70 CONTINUE
SDX=VARX**.5
SDY=VARY**.5
DO 100 K=1,MAXM
KL=51+K
LAG=N-K
DO 90 J=1,LAG
IJ=J+K
RXX(K)=RXX(K)+X(J)*X(IJ)/N
RYY(K)=RYY(K)+Y(J)*Y(IJ)/N
RXY(K)=RXY(K)+X(J)*Y(IJ)/N
RXY(KL)=RXY(KL)+X(IJ)*Y(J)/N
90 CONTINUE
100 CONTINUE
STD=(VARX*VARY)**0.5
RXY(51)=RXY(51)/STD
DO 130 K=1,MAXM
KL=51+K
RXX(K)=RXX(K)/VARX
RYY(K)=RYY(K)/VARY
RXY(K)=RXY(K)/STD
RXY(KL)=RXY(KL)/STD
130 CONTINUE
RETURN
END
SUBROUTINE ACOR
COMMON ACOR,XX(300),PCR(20,20),CXX(20)
COMMON /AC1/ N,X(300),SDX,COR(20),PCOR(20)
DO 10 I=1,N
XX(I)=X(I)
```

UTID (Cont'd)

```
10 CONTINUE
DO 35 I=1,20
CXX(I)=0
COR(I)=0
35 CONTINUE
XM=0
DO 40 I=1,N
XM = XM + XX(I)/N
40 CONTINUE
DO 60 I=1,N
XX(I)=XX(I)-XM
60 CONTINUE
VAR=0
DO 25 I=1,N
VAR=VAR+XX(I)*XX(I)/N
25 CONTINUE
DO 100 K=1,NCOR
LAG = N-K
DO 90 J=1,LAG
IJ=J+K
CXX(K)=CXX(K)+XX(J)*XX(IJ)/N
90 CONTINUE
COR(K)=CXX(K)/VAR
100 CONTINUE
PCR(1,1)=COR(1)
PCOR(1)=COR(1)
DO 300 L=2,NCOR
SUM1=0
SUM2=0
L1=L-1
L2=L1-1
DO 310 J=1,L1
LJ=L1-J
IF (L1-J) 400,401,400
400 PCR(L1,J)=PCR(L2,J)-PCR(L1,L1)*PCR(L2,LJ)
401 LJ1=L-J
SUM1=SUM1+PCR(L1,J)*COR(LJ1)
SUM2=SUM2+PCR(L1,J)*COR(J)
310 CONTINUE
PCR(L,L)=(COR(L)-SUM1)/(1.-SUM2)
PCOR(L)=PCR(L,L)
300 CONTINUE
SDX=VAR**.5
RETURN
END
```

Program 5 - UTPE

```
10 * PROGRAM 6.        UNIVARIATE TRANSFER FUNCTION MODEL
20 *                    PRELIMINARY ESTIMATION   (UTPE)                *
30 *                                                                    *
40 * THIS PROGRAM COMPUTES FOR THE TRANSFER FUNCTION-NOISE MODEL THE    *
50 * FOLLOWING INITIAL ESTIMATES:                                       *
60 *        DELTA   -  LEFT-HAND SIDE PARAMETERS (1 TO R)               *
70 *        OMEGA   -  RIGHT-HAND SIDE PARAMETERS (0 TO S)              *
80 *        PHI     -  AUTOREGRESSIVE PARAMETERS (1 TO P)               *
90 *        THETA   -  MOVING AVERAGE PARAMETERS (1 TO Q)               *
100 *       SIGMA2  -  WHITE NOISE VARIANCE.                            *
110 *                                                                   *
120 * THE PROGRAM REWUIRES DATA FROM A FILE CALLED PR5OUT WHICH CON-    *
130 * TAINS THE FOLLOWING VALUES:                                      *
140 *       F, NO. OF IMPULSE RESPONSE WEIGHTS                         *
150 *       IMPULSE RESPONSE WEIGHTS (0 TO F)                           *
160 *       NOISE AUTOCORRELATIONS (1 TO F)                             *
170 *       NOISE AUTOCOVARIANCE (LAG 0).                               *
180 *                                                                   *
190 DIMENSION A(10,11),KWA(10),OMEGA(10),VEE(30),DELTA(10)
200 COMMON IF,COV(30),MXROW,IP,IQ,PHI(10),THETA(10)
210 MXROW = 10
220 * INPUT NECESSARY PARAMETER ON THE FILE SIZE    *
230 CALL DEFINE(1,'PR5OUT,')
240 READ(1,12) IF
250 12 FORMAT(I4)
260 IF1 = IF+1
270 READ(1,13)  (VEE(I),I=1,IF1),(COV(I),I=2,IF1),DENOM
280 COV(1) = 1
290 13 FORMAT(F12.6)
300 * CONVERT AUTOCORRELATIONS INTO AUTOCOVARIANCES  *
310 DO 91 I = 1,IF1
320 COV(I) = COV(I)*DENOM
330 91 CONTINUE
340 * INPUT OTHER PARAMETER FROM THE TERMINAL   *
350 GO TO 5031
360 * CHECK PARAMETERS  *
370 50 IF(IF .LT. IB+IS+IR) GO TO 5031
380 IR1 = IR+1
390 IS1 = IS+1
400 IB1 = IB+1
410 * CALCULATE ESTIMATES DELTA(I),I=1 TO IR, OF LEFT-HAND SIDE  *
420 * TRANSFER FUNCTION PARAMETERS, STORED IN A(I,IR+1),I=1 TO IR  *
430 DO 933 I=1,IR
440 DELTA(I) = 0.
450 933 CONTINUE
```

```
IF(IR .LE. 0) GO TO 60
DO 40 I=1,IR
DO 45 J=1,IR
IND = IB+IS+I-J+1
A(I,J) = VEE(IND)
IF(IS+I .LT. J) A(I,J) = 0.
45 CONTINUE
IND = IB+IS+I+1
A(I,IR1) = VEE(IND)
40 CONTINUE
NIR1 = -IR1
CALL MATINV(ISOL,IDSOL,IR,NIR1,A,NMROW,KMA,DET)
IF(ISOL-2) 220,221,222
221 WRITE(9,224) ISOL
224 FORMAT('ISOL =',I3,2X,'UNABLE TO SOLVE FOR DELTA.')
GO TO 500
222 WRITE(9,223) ISOL
223 FORMAT('ISOL =',I3,2X,'INPUT ERROR FOR DELTA SOLUTION.')
GO TO 500
220 IF(IDSOL .EQ. 1) GO TO 230
WRITE(9,225)
225 FORMAT('DELTA DETERMINANT CALCULATION OVERFLOW.')
GO TO 500
230 CONTINUE
DO 931 I=1,IR
DELTA(I) = A(I,IR1)
931 CONTINUE
* CALCULATE ESTIMATES OMEGA(J), J=0 TO IS, OF RIGHT-HAND SIDE
* TRANSFER FUNCTION PARAMETERS.
60 DO 932 I=1,IS1
OMEGA(I) = 0.
932 CONTINUE
OMEGA(1) = VEE(IB1)
IF(IR .EQ. 0) GO TO 701
IMIN = MIN0(IR,IS)
DO 70 J=1,IMIN
DO 80 I = 1,J
J1 = J+1
IND = IB+J-I+1
OMEGA(J1) = OMEGA(J1) + DELTA(I)*VEE(IND)
80 CONTINUE
IND = IB+J+1
OMEGA(J1) = OMEGA(J1) - VEE(IND)
70 CONTINUE
701 IF(IR .GE. IS) GO TO 90
DO 75 J=IR1,IS
J1 = J+1
IF(IR .EQ. 0) GO TO 702
DO 85 I=1,IR
IND = IB+J-I+1
OMEGA(J1) = OMEGA(J1) + DELTA(I)*VEE(IND)
85 CONTINUE
```

UTPE (Cont'd)

```
702 IND = IB+J+1
OMEGA(J1) = OMEGA(J1) - VEE(IND)
75 CONTINUE
90 CONTINUE
770 WRITE (9,771) IR,IS,IB
771 FORMAT(5X,'R=',I3,4X,'S=',I3,4X,'B=',I3)
WRITE(9,772)
772 FORMAT(4X,'I',5X,'V(I)',3X,'DELTA(I)',2X,'OMEGA(I)')
DO 780 I=0,IF
I1=I+1
IF(I .EQ. 0) GO TO 783
IF (IR.GE.I) GOTO 781
IF (IS.GE.I) GOTO 783
WRITE (9,790) I,VEE(I1)
790 FORMAT(3X,I2,2X,F8.3)
GOTO 780
781 IF (IS.GE.I) GOTO 785
WRITE (9,791) I,VEE(I1),DELTA(I)
791 FORMAT(3X,I2,2X,F8.3,2X,F8.3)
GOTO 780
785 WRITE (9,792) I,VEE(I1),DELTA(I),OMEGA(I1)
792 FORMAT(3X,I2,2X,F8.3,2X,F8.3,2X,F8.3)
GOTO 780
783 WRITE (9,793) I,VEE(I1),OMEGA(I1)
793 FORMAT(3X,I2,2X,F8.3,12X,F8.3)
780 CONTINUE
GOTO 800
500 WRITE (9,501)
501 FORMAT('CHANGE INPUTS? YES-1,NO-CR.')
810 READ (9,502) IX
502 FORMAT(I2)
IF (IX.EQ.0) GOTO 900
5031 WRITE(9,503) IF
503 FORMAT(/,'ENTER R,S,B WITH R+S+B.LE.',I3,'.',5X)
READ (9,504) IR,IS,IB
504 FORMAT(3I3)
GOTO 50
800 WRITE(9,801)
801 FORMAT('CHANGE INPUTS? YES-1,NO-CR.',5X)
GOTO 810
900 CALL USPE2
WRITE(9,1952)
1952 FORMAT(/,5X,'START OVER WITH R,S,B?  YES-1,NO-CR.')
READ(9,1042) IX
IF(IX .EQ. 1) GO TO 5031
WRITE(9,1041)
1041 FORMAT(5X,'CREATE A FILE?  YES-1,NO-CR.')
READ(9,1042) IX
1042 FORMAT(I2)
IF(IX .EQ. 0) GO TO 999
CALL DEFINE(1,'PR6OUT,')
```

```
WRITE(1,1043) IR,IS,IB,IP,IQ
1043 FORMAT(I3)
IF (IR.NE.0) WRITE(1,1044)(DELTA(I),I=1,IR)
*         IS1=S+1, HENCE IS1 IS ALWAYS GREATER THAN ZERO
WRITE(1,1044)(OMEGA(I),I=1,IS1)
IP1 = IP+1
IQ1 = IQ+1
IF (IP.NE.0) WRITE(1,1044)(PHI(I),I=2,IP1)
IF (IQ.NE.0) WRITE(1,1044)(THETA(I),I=2,IQ1)
1044 FORMAT(F12.6)
REWIND 1
CALL DSAVE(1,ISTAT)
WRITE(9,1045)
1045 FORMAT(5X,'FILE PR6OUT CREATED.')
999 STOP
END
*
* THE FOLLOWING SUBROUTINE IS A MINOR MODIFICATION OF PROGRAM 2.
*
SUBROUTINE USPE2
DIMENSION KNA(10),A(10,10),CPR(30),TAU(10),T1(10,10)
DIMENSION T2(10,10),T(10,10),F(10),H(10)
COMMON IF,COV(30),MXROW,IP,IQ,PHI(10),THETA(10)
WRITE (9,10)
10 FORMAT(/,'ENTER P, Q, EPSILON,AND MAXITER.')
READ (9,11) IP,IQ,EPSLON,ITMAX
11 FORMAT(2I4,F10.4,I4)
IK = IF
* COV(K) = K-1 ST AUTOCOVARIANCE OF W SEQUENCE.
* IP = NUMBER OF AUTOREGRESSIVE PARAMETERS.
* IQ = NUMBER OF MOVING AVERAGE PARAMETERS.
* IK = NUMBER OF COVARIANCE LAGS.
50 DO 1214 I=1,10
PHI(I) = 0.
THETA(I) = 0.
1214 CONTINUE
IF (IP.EQ.0) GOTO 300
DO 100 I=1,IP
DO 110 J=1,IP
IC=IABS(IQ+I-J)+1
A(I,J)=COV(IC)
110 CONTINUE
J1=J+1
IA=IQ+I+1
A(I,J1)=COV(IA)
100 CONTINUE
IP1=-(IP+1)
CALL MATINV(ISOL,IDSOL,IP,IP1,A,MXROW,KNA,DET)
ITER=0
IF (ISOL-2) 120,121,122
121 WRITE (9,124) ISOL
124 FORMAT('ISOL =',I3,2X,'UNABLE TO SOLVE FOR PHI.')
```

```
GOTO 500
122 WRITE (9,123) ISOL
123 FORMAT('ISOL =',I3,2X,'INPUT ERROR FOR PHI SOLUTION.')
GOTO 500
120 IF (IDSOL.EQ.1) GOTO 130
WRITE (9,125)
125 FORMAT('PHI DETERMINANT CALCULATION OVERFLOW.')
GOTO 500
130 ICOL=IP+1
PHI(1)=-1.0
DO 135 I=1,IP
I1=I+1
PHI(I1)=A(I,ICOL)
135 CONTINUE
IF(IQ .EQ. 0) GO TO 730
DO 200 J=0,IQ
SUM=0
DO 210 I=0,IP
DO 210 K=0,IP
IJK=IABS(J+I-K)+1
I1=I+1
K1=K+1
SUM=SUM+PHI(I1)*PHI(K1)*COV(IJK)
210 CONTINUE
J1=J+1
CPR(J1)=SUM
200 CONTINUE
GOTO 350
300 DO 310 J=0,IQ
J1=J+1
CPR(J1)=COV(J1)
310 CONTINUE
350 TAU(1)=CPR(1)**.5
DO 400 I=1,IQ
I1=I+1
TAU(I1)=0
400 CONTINUE
ITER = 1
650 DO 410 I=0,IQ
DO 410 J=0,IQ
I1=I+1
J1=J+1
T1(I1,J1)=0
T2(I1,J1)=0
410 CONTINUE
DO 420 I=0,IQ
IJ=IQ-1
DO 420 J=0,IJ
JP=I+1+J
J1=J+1
I1=I+1
```

```
T1(I1,J1)=TAU(JP)
T2(I1,JP)=TAU(J1)
420 CONTINUE
I01=I0+1
DO 430 I=1,I01
DO 430 J=1,I01
T(I,J)=T1(I,J)+T2(I,J)
430 CONTINUE
DO 440 J=0,I0
J1=J+1
I02=I0-J
F(J1)=-CPR(J1)
DO 440 I=0,I02
I1=I+1
IJ=I1+J
F(J1)=F(J1)+TAU(I1)*TAU(IJ)
440 CONTINUE
I02=I0+2
DO 450 J=0,I0
J1=J+1
T(J1,I02)=F(J1)
450 CONTINUE
I02=-I02
CALL MATINV(ISOL,IDSOL,I01,I02,T,10,KWA,DET)
IFLAG=1
IF (ISOL-2) 460,461,462
461 WRITE(9,463) ISOL
463 FORMAT('ISOL=',I3,2X,'UNABLE TO SOLVE FOR H.')
GOTO 500
462 WRITE(9,464) ISOL
464 FORMAT('ISOL=',I3,2X,'INPUT ERROR FOR H SOLUTION.')
GOTO 500
460 IF (IDSOL.EQ.1) GOTO 600
WRITE(9,465)
465 FORMAT('H DETERMINANT CALCULATION OVERFLOW.')
GOTO 500
600 I02=I0+2
DO 610 I=0,I0
I1=I+1
H(I1)=T(I1,I02)
TAU(I1)=TAU(I1)-H(I1)
610 CONTINUE
DO 620 I=0,I0
I1=I+1
FABS=ABS(F(I1))
IF (FABS.GE.EPSLON) GOTO 630
620 CONTINUE
GO TO 700
630 IF (ITER.GE.ITMAX) GOTO 640
ITER =ITER+1
GOTO 650
```

```
640 WRITE(9,641)
641 FORMAT('MAXIMUM ITERATIONS FOR TAU EXCEEDED.')
GOTO 500
700 DO 710 J=1,10
J1=J+1
THETA(J1)=-TAU(J1)/TAU(1)
710 CONTINUE
730 IF (IQ.GT.0) GOTO 750
SUM=0
DO 760 I=1,IP
I1=I+1
SUM=SUM+PHI(I1)*COV(I1)
760 CONTINUE
SIGMA2=COV(1)-SUM
GOTO 770
750 SIGMA2=TAU(1)*TAU(1)
770 WRITE (9,771) IP,IQ,SIGMA2
771 FORMAT(5X,'P=',I3,4X,'Q=',I3,4X,'SIGMA2=',F10.3)
WRITE(9,772)
772 FORMAT(/,4X,'I',5X,'COV(I)',3X,'PHI(I)',2X,'THETA(I)')
DO 780 I=0,IK
I1=I+1
IF(I .EQ. 0) GO TO 787
IF (IP.GE.I) GOTO 781
IF (IQ.GE.I) GOTO 783
WRITE (9,790) I,COV(I1)
790 FORMAT(3X,I2,2X,F8.3)
GOTO 780
781 IF (IQ.GE.I) GOTO 785
WRITE (9,791) I,COV(I1),PHI(I1)
791 FORMAT(3X,I2,2X,F8.3,2X,F8.3)
GOTO 780
787 WRITE(9,794) I,COV(I1)
794 FORMAT(3X,I2,2X,F8.3)
GO TO 780
785 WRITE (9,792) I,COV(I1),PHI(I1),THETA(I1)
792 FORMAT(3X,I2,2X,F8.3,2X,F8.3,2X,F8.3)
GOTO 780
783 WRITE (9,793) I,COV(I1),THETA(I1)
793 FORMAT(3X,I2,2X,F8.3,12X,F8.3)
780 CONTINUE
GOTO 800
500 WRITE (9,501)
501 FORMAT('CHANGE INPUTS? YES-1,NO-CR.')
810 READ (9,502) IX
502 FORMAT(I2)
IF (IX.EQ.0) GOTO 900
WRITE (9,503) IK
503 FORMAT(/,'ENTER NEW P AND Q. P+Q.LE.',I3,'.',5X)
READ (9,504) IP,IQ
504 FORMAT(2I3)
```

UTPE (Cont'd)

```
WRITE(9,506)
506 FORMAT(/,'ENTER NEW EPSILON,MAXITER. NO CHANGE- CR.',5X)
READ (9,507) DELTA,IX
507 FORMAT(F10.6,I5)
IF (IX.EQ.0) GOTO 50
EPSLON=DELTA
ITMAX=IX
GOTO 50
800 WRITE(9,801)
801 FORMAT('CHANGE INPUTS? YES-1,NO-CR.',5X)
GOTO 810
900 RETURN
END
```

Program 6 - UTES

```
10 *                    MAIN ROUTINE
20 *THIS PROGRAM USES AN ITERATIVE NON-LINEAR LEAST SQUARES ESTIMATION
30 *PROCEDURE TO OBTAIN ESTIMATES OF TRANSFER FUNCTION PARAMETERS
40 *
50 *LIST OF GLOBAL VARIABLES:
60 *  R - NUMBER OF LEFT-HAND-SIDE TRANSFER FUNCTION PARAMETERS
70 *  S - NUMBER OF RIGHT-HAND-SIDE TRANSFER FUNCTION PARAMETERS (LESS 1)
80 *  B - DELAY PARAMETER
90 *  P - NUMBER OF NOISE AUTOREGRESSIVE PARAMETERS
100 *  Q - NUMBER OF NOISE MOVING AVERAGE PARAMETERS
110 *  N - LENGTH OF ONPUT AND PUTPUT SERIES (LATER DECREASED BY 1)
120 *  K - MAX NUMBER OF AUTO- AND CROSS-CORRELATION LAGS
130 *
140 *  DELTA - LHS TRANSFER FUNCTION PARAMETERS
150 *  OMEGA0 - FIRST RHS TRANSFER FUNCTION PARAMETER
160 *  OMEGA - OTHER RHS TRANSFEER FUNCTION PARAMETERS
170 *  PHI - NOISE AR PARAMETERS
180 *  THETA - NOISE MA PARAMETERS
190 *
200 *  PPRIME - NUMBER OF AR PARAMETERS IN NOISE MODEL
210 *  QPRIME - NUMBER OF MA PARAMETRRS IN NOISE MODEL
220 *  PHIP - AR PARAMETERS IN NOISE MODEL
230 *  THETAP - MA PARAMETERS IN NOISE MODEL
240 *
250 *  X - INPUT SERIES
260 *  BETA - DELTA,OMEGA0,OMEGA,PHI,THETA CONCATENATED
270 *  Y - OUTPUT SERIES
280 *
290 *  VAROFA - RESIDUAL VARIANCE
300 *  COVMAT - COVARIANCE MATRIX FOR ESTIMATES
310 *  STDDEV - STANDARD DEVIATION VECTOR FOR ESTIMATES
320 *  CORREL - CORRELATION MATRIX FOR ESTIMATES
330 *  RAA - RESIDUAL AUTOCORRELATION FUNCTION
340 *  PCHISQ - CHI-SQUARE STATISTIC FOR RESIDUAL AUTOCORRELATIONS
350 *  RALA0 - INPUT-RESIDUAL CROSSCORRELATION COEFFICIENT OF LAG 0
360 *  RALA - REMAINING INPUT- RESIDUAL CROSSCORRELATION COEFFICIENTS
370 *  QCHISQ - CHI-SQUARE STATISTIC FOR I-R CROSSCORRELATIONS
380 *  QDF - DEGREES OF FREEDOM ASSOCIATED WITH QCHISQ
390 *
400 *  NBETA - LENGTH OF BETA-VECTOR
410 *  NRESID - NUMBER OF RESIDUALS
420 *  RESID - VECTOR OF RESIDUALS
430 *  SUMSQ - SUM OF SQUARES OF RESIDUAL
440 *  AINV - USED IN CALCULATING COVMAT,STDDEV, AND R
450 *
```

```
        COMMON/PARAM1/R,S,B,P,Q,N,K
  +           /PARAM3/DELTA,OMEGA0,OMEGA,PHI,THETA
  +           /PARAM4/PPRIME,QPRIME,PHIP,THETAP
  +           /SERIES/X,DUMMY(15),BETA,Y
  +           /STAT/VAROFA,COVMAT,STDDEV,CORREL,RAA,PCHISQ,PDF,RALA0,
  +                 RALA,QCHISQ,QDF
        INTEGER R,S,B,P,Q,N,K,D,PPRIME,QPRIME,PDF,QDF,NBETA,NRESID
        REAL DELTA,OMEGA0,OMEGA,PHI,THETA,PHIP,THETAP,X,Y,
  +          BETA,VAROFA,STDDEV,COVMAT,R,RAA,PCHIDQ,RALA0,RALA,QCHISQ,
  +          RESID,SUMSQ,AINV
        DIMENSION DELTA(5),OMEGA(5),PHI(5),THETA(5),PHIP(5),THETAP(5),
  +               X(50),Y(50),COVMAT(10,10),STDDEV(10),CORREL(10,10),
  +               RAA(30),RALA(30),AINV(10,10),BETA(10),RESID(50)
  *
  *THE DATA IS READ IN
        CALL INPUT7
  *THE LEAST SQUARES ESTIMATES OF THE PARAMETERS ARE CALCULATED
        CALL ESTIM(NBETA,NRESID,RESID,SUMSQ,AINV)
  *STATISTICS ON THE SESIMATES ARE CALCULATED
        CALL STATS7(NBETA,NRESID,RESID,SUMSQ,AINV)
  *THE STATISTICS AND RESIDUALS ARE PRINTED
        CALL OUTPT7(NBETA,NRESID,RESID)
        STOP
        END
  *SUBPROGRAM TO READ DATA AND PARAMETERS
  *
        SUBROUTINE INPUT7
  *
        COMMON/PARAM1/R,S,B,P,Q,N,K
  +           /PARAM3/ DELTA,OMEGA0,OMEGA,PHI,THETA
  +           /PARAM4/PPRIME,QPRIME,PHIP,THETAP
  +           /SERIES/X,DUMMY(25),Y
        INTEGER R,S,B,P,Q,N,K,D,PPRIME,QPRIME,I
        REAL X,Y,DELTA,OMEGA0,OMEGA,PHI,THETA,PHIP,THETAP
        DIMENSION DELTA(5),OMEGA(5),PHI(5),THETA(5),PHIP(5),THETAP(5),
  +               X(50),Y(50)
        WRITE(9,100)
    100 FORMAT(' TYPE MAX. NUMBER OF CORRELATION LAGS')
        READ(9,300) K
  *                           ORIGINAL SERIES DATA
        CALL DEFINE(1,'XFILE,')
        CALL DEFINE(2,'YFILE,')
        READ(1,300) N
        READ(1,200)(X(I),I=1,N)
        READ(2,300) N
        READ(2,200)(Y(I),I=1,N)
  *                           TRANSFER FUNCTION PARAMETERS
        CALL DEFINE(3,'PRGOUT,')
        READ(3,300) R
        READ(3,300) S
        READ(3,300)B
```

```
      READ(3,300) P
      READ(3,300) Q
      IF (R.NE.0) READ(3,200)(DELTA(I),I=1,R)
      READ(3,200) OMEGA0
      IF (S.NE.0) READ (3,200)(OMEGA(I),I=1,S)
      IF (P.NE.0) READ(3,200)(PHI(I),I=1,P)
      IF (Q.NE.0) READ(3,200)(THETA(I),I=1,Q)
*                               NOISE SERIES PARAMETRRS
      CALL DEFINE(4,'FWHITE;')
      READ(4,300) PPRIME
      READ(4,300) QPRIME
      IF (PPRIME.NE.0) READ(4,200)(PHIP(I),I=1,PPRIME)
      IF (QPRIME.NE.0) READ(4,200)(THETAP(I),I=1,QPRIME)
      RETURN
  200 FORMAT(F12.6)
  300 FORMAT(I4)
      END
* SUBPROGRAM TO PRODUCE LEAST-SQUARES ESTIMATES FOR TRANSFER FUNCTION
* PARAMETERS.  ESTIM CONSTRUCTS THE VECTOR OF INITIAL PARAMETER
* ESTIMATES FROM INPUT, THEN CALLS MARQUA, WHICH USES AN ITERATIVE LEAS
* SQUARES PROCEDURE ON THE VECTOR, BETA
*
      SUBROUTINE ESTIM(NBETA,NRESID,RESID,SUMSQ,AINV)
*
      COMMON/PARAM1/R,S,B,P,Q,N
+           /PARAM3/DELTA,OMEGA0,OMEGA,PHI,THETA
+           /SERIES/DUMMY(65),BETA
      INTEGER R,S,B,P,Q,N,I,H,NBETA,NRESID
      REAL DELTA,OMEGA0,OMEGA,PHI,THETA,BETA
      DIMENSION DELTA(5),OMEGA(5),PHI(5),THETA(5),BETA(10),RESID(50),
+                AINV(10,10),WORK1(65),WORK2(10)
*                               CONSTRUCT BETA
   10 IF (R.EQ.0) GOTO 20
      DO 11 I=1,R
      BETA(I)=DELTA(I)
   11 CONTINUE
   20 H=R+1
      BETA(H)=OMEGA0
      IF (S.EQ.0) GOTO 30
      DO 21 I=1,S
      H=H+1
      BETA (H)=OMEGA(I)
   21 CONTINUE
   30 IF (P.EQ.0) GOTO 40
      DO 31 I=1,P
      H=H+1
      BETA(H)=PHI(I)
   31 CONTINUE
   40 IF (Q.EQ.0) GOTO 50
      DO 41 I=1,Q
      H=H+1
```

```
        BETA(N)=THETA(I)
   41   CONTINUE
*             .NBETA=# OF PARAMETERS
   50   NBETA=N
*                NRESID=# OF RESIDUALS
        NRESID=N-S-B-P
*                                DO LEAST SQUARES PROCEDURE
        CALL MARQUA(NBETA,NBETA+1,NRESID,.01,.00001,.1,100.,.001,
+                       WORK1,WORK2,AINV,RESID,SUMSQ)
        CALL DEFINE(5,'MODEL ')
        WRITE(5,100) R,S,B,P,Q
  100   FORMAT(5(I4,/))
        WRITE(5,200)(BETA(I),I=1,NBETA)
  200   FORMAT(F12.6)
        RETURN
        END
*SUBPROGRAM TO DO NON-LINEAR LEAST SQUARES ESTIMATION
*
         SUBROUTINE MARQUA(NBETA,NBETA1,NRESID,P1,EPS,F2,UDPI,DELTA,
+                          RESIDT,KWA,A,RESID,SUMSQ)
*
        COMMON/PARAM1/IDUMMY(5),NN
+             /SERIES/DUMMY(65),BETA
         INTEGER NN,NBETA,NBETA1,NRESID,I,J,T
         REAL P1,EPS,F2,UDPI,DELTA,RESID,KWA,A,RESID,SUMSQ,RESIDT,SUMSQT,A
+            X,G,ASTAR,D,H,BETOLD
         DIMENSION RESID(50),RESIDT(50),BETA(10),BETOLD(10),A(10,10),
+                  X(10,50),G(10),ASTAR(10,11),D(10),H(10)
*                                     CALCULATE NEGATIVE OF JACOBIAN
         CALL CRESID(RESID,SUMSQ)
         WRITE(9,5000)(BETA(J),J=1,NBETA)
  5000   FORMAT(' INITIAL BETAS: '6F10.5,/,4F10.5)
         WRITE(9,6000) SUMSQ
  6000   FORMAT(' INITIAL SUN OF SQUARES: ',F10.5)
  10    DO 1 I=1,NBETA
         BETA(I)=BETA(I)+DELTA
         CALL CRESID(RESIDT,SUMSQT)
   .WRITE(9,1000)(BETA(J),J=1,NBETA)
 1000 FORMAT(F12.5)
         BETA(I)=BETA(I)-DELTA
         DO 11 T=1,NN
         X(I,T)=(RESID(T)-RESIDT(T))/DELTA
 .WRITE(9,2000) I,T,X(I,T)
 2000 FORMAT(' X(',I1,',',I2,')=',E15.6)
  11     CONTINUE
  1      CONTINUE
*                                    CALCULATE REGRESSION MATRIX
         DO 2 I=1,NBETA
         DO 21 J=1,NBETA
         A(I,J)=0.
         DO 211 T=1,NN
```

```
            A(I,J)=A(I,J)+X(I,T)*X(J,T)
      211   CONTINUE
      21    CONTINUE
            G(I)=0
            DO 22 T=1,NN
          G(I)=G(I)+X(I,T)*RESID(T)
      22    CONTINUE
            D(I)=SQRT(A(I,I))
      2     CONTINUE
     *                              SOLVE FOR INCREMENT VECTOR
     *                      1. CONSTRUCT A*,G*
      30    DO 3 I=1,NBETA
            ASTAR(I,I)=1.+PI
            ASTAR(I,NBETA1)=G(I)/D(I)
            DO 31 J=1,NBETA
            IF (I.NE.J) ASTAR (I,J)=A(I,J)/(D(I)*D(J))
      31    CONTINUE
      3     CONTINUE
     *                      2. SOLVE FOR H
            CALL MATINV(ISOL,IDSOL,NBETA,-NBETA1,ASTAR,10,KWA,DET)
            DO 4 J=1,NBETA
            H(J)=ASTAR(J,NBETA1)/D(J)
            BETOLD(J)=BETA(J)
            BETA(J)=BETA(J)+H(J)
      4     CONTINUE
     *                              TEST FOR IMPROVEMENT
            CALL CRESID(RESIDT,SUMSQT)
          WRITE(9,1000)(BETA(J),J=1,NBETA)
            IF (SUMSQT.GT.SUMSQ) GOTO 60
     *                               IF NEW BETA IS BETTER (OR AS GOOD)
            DO 51 I=1,NBETA
            IF (ABS(H(I)).GE.EPS) GOTO 50
      51    CONTINUE
     *                      1. IF PROCEDURE HAS CONVERGED, QUIT
            DO 52 I=1,NBETA
            BETA(I)=BETOLD(I)
      52    CONTINUE
            GOTO 70
     *                      2. IF NOT CONVERGED, PROCEED TO NEXT ITERATION
      50    PI=PI*F2
            DO 53 T=1,NN
            RESID(T)=RESIDT(T)
      53    CONTINUE
            SUMSQ=SUMSQT
            WRITE(9,3000)(BETA(I),I=1,NBETA)
     3000   FORMAT(' NEW BETAS: ',6F10.5,/,4F10.5)
            WRITE(9,7000)  SUMSQ
     7000   FORMAT(' NEW SUM OF SQUARES: ',F10.5)
            GOTO 10
     *                               IF NEW BETA IS WORSE, FIND NEW
            PI=PI/F2
```

```
      DO 6 I=1,NBETA
      BETA(I)=BETOLD(I)
 6    CONTINUE
*                               IF PI TOO LARGE, QUIT
      IF (PI.LE.USPI) GOTO 30
*                                     QUIT, BUT FIRST FIND A-INVERSE
 70   CALL MATINV(ISOL,IDSOL,NBETA,NBETA,A,10,KNA,DET)
      WRITE(9,4000) (BETA(I),I=1,NBETA)
 4000 FORMAT(' FINAL BETAS: ',6F10.5,/,4F10.5)
      WRITE(9,8000) SUMSQ
 8000 FORMAT(' FINAL SUM OF SQUARES: ',F10.5)
      RETURN
      END
* THIS IS A SUBPROGRAM TO COMPUTE RESIDUALS BASED ON A TRANSFER FUNCTION
* MODEL
*
      SUBROUTINE CRESID(RESID,SUMSQ)
*
      COMMON/PARAM1/R,S,B,P,Q,N
     +       /SERIES/X,DUMMY(15),BETA,Y
      INTEGER R,S,B,P,Q,N,I,J,BS1,BSP,BSP1,H,HBETA,R1,R1S,R1SP
      REAL RESID,SUMSQ,DELTA,OMEGA0,OMEGA,PHI,THETA,SCRIPT,SMALLN
      DIMENSION BETA(10),X(50),Y(50),RESID(50),SCRIPT(50),SMALLN(50)
      EQUIVALENCE (SCRIPT(1),SMALLN(1))
      BS1=B+S+1
      BSP=B+S+P
      BSP1=BSP+1
      R1=R+1
      R1S=R1+S
      R1SP=R1S+P
      SUMSQ=0.
*          PART 1:  SCRIPT-Y
      DO 11 I=1,N
      SCRIPT(I)=0.
 11   CONTINUE
      DO 12 I=BS1,N
      IF (R.EQ.0) GOTO 120
      DO 121 J=1,R
      H=I-J
      SCRIPT(I)=SCRIPT(I)+BETA(J)*SCRIPT(H)
 121  CONTINUE
 120  H=I-B
      HBETA=R+1
      SCRIPT(I)=SCRIPT(I)+BETA(HBETA)*X(H)
      IF (S.EQ.0) GOTO 12
      DO 122 J=1,S
      H=H-1
      HBETA=R1+J
      SCRIPT(I)=SCRIPT(I)-BETA(HBETA)*X(H)
 122  CONTINUE
 12   CONTINUE
```

```
*              PART 2:  SMALL-N
          DO 2 I=1,N
          SMALLN(I)=Y(I)-SCRIPT(I)
     2    CONTINUE
*              PART 3:  A (THE RESIDUALS)
          DO 31 I=1,BSP
          RESID(I)=0.
    31    CONTINUE
          DO 32 I=BSP1,N
          RESID(I)=SMALLN(I)
          IF (P.EQ.0) GOTO 3201
          DO 321 J=1,P
          H=I-J
          NBETA=R1S+J
          RESID(I)=RESID(I)-BETA(NBETA)*SMALLN(H)
   321    CONTINUE
   3201 IF (Q.EQ.0) GOTO 3202
          DO 322 J=1,Q
          H=I-J
          NBETA=R1SP+J
          RESID(I)=RESID(I)+BETA(NBETA)*RESID(H)
   322    CONTINUE
   3202 SUMSQ=SUMSQ+RESID(I)*RESID(I)
 .WRITE(9,2000) I,RESID(I)
 2000 FORMAT(' RESID(',I2,')=',E15.6)
    32    CONTINUE
          RETURN
          END
* SUBPROGRAM TO CALCULATE SUMMARY STATISTICS ON ESTIMATION PROCEDURE
*
          SUBROUTINE STATS7(NBETA,NRESID,A,SUMSQ,AINV)
*
          COMMON/PARAM1/R,S,B,P,Q,N,K
 +             /PARAM4/PPRIME,QPRIME,PHIP,THETAP
 +             /SERIES/X,DUMMY(25),Y
 +             /STAT/VAROFA,COVMAT,STDDEV,CORREL,RAA,PCHISQ,PDF,RALAO,
 +                   RALA,QCHISQ,QDF
          INTEGER R,S,B,P,Q,N,K,PPRIME,QPRIME,PDF,QDF,NBETA,NRESID,
 +               NSBP1,SBP1,H,V1,NMINK,T,I,J,PPP1
          REAL PHIP,THETAP,VAROFA,COVMAT,STDDEV,CORREL,RAA,PCHISQ,RALAO,RALA,
 +             QCHISQ,A,SUMSQ,ABAR,ASQ,CAAO,CAA,ALFBAR,ALFSQ,ALPHA,CALAO
 +             ,DENOM,CALAO,CALA,AINV
          DIMENSION PHIP(5),THETAP(5),COVMAT(10,10),STDDEV(10),CORREL(10,10),
 +                   RAA(30),RALA(30),A(50),CAA(30),CALA(30),
 +                   AINV(10,10),ALPHA(50),X(50),Y(50)
          EQUIVALENCE (RAA(1),CAA(1)),(RALA(1),CALA(1)),(SBP1,V1)
*
```

UTES (Cont'd)

```
*                                VARIANCE OF RESIDUALS
          VAROFA=SUMSQ/(N-R-B-Q-2*(S+P)-1)
*
*                                COVARIANCE AND CORRELATION OF ESTIMATES
          DO 1 I=1,NBETA
          DO 11 J=1,NBETA
          COVMAT(I,J)=A1NV(I,J)*VAROFA
   11     CONTINUE
          STDDEV(I)=SQRT(COVMAT(I,I))
    1     CONTINUE
          DO 2 I=1,NBETA
          DO 21 J=1,NBETA
          CORREL(I,J)=COVMAT(I,J)/(STDDEV(I)*STDDEV(J))
   21     CONTINUE
    2     CONTINUE
*
*                                RESIDUAL AUTOCORRELATION FUNCTION
          ASQ=0
          ABAR=0
          PCHISQ=0.
          NRES1=NRESID+1
          SBP1=S+B+P+1
          DO 3 I=SBP1,N
          ABAR=ABAR+A(I)
          ASQ=ASQ+A(I)*A(I)
    3     CONTINUE
          ABAR=ABAR/NRES1
          ASQ=ASQ/NRES1
*         CAAI IS SAMPLE AUTOCOVARIANCE, LAG I
          CAA0=ASQ-ABAR*ABAR
          DO 4 I=1,K
          CAA(I)=0.
          NMINK=N-I
          DO 41 J=SBP1,NMINK
          H=I+J
          CAA(I)=CAA(I)+(A(J)-ABAR)*(A(H)-ABAR)
   41     CONTINUE
          CAA(I)=CAA(I)/NRES1
          RAA(I)=CAA(I)/CAA0
          PCHISQ=PCHISQ+RAA(I)*RAA(I)
    4     CONTINUE
          PCHISQ=(N-S-B-P)*PCHISQ
          PDF=K-P-Q
*
*                                INPUT-RESIDUAL CROSSCORRELATION FUNCTION
*                     1.PREWHITEN X
          IF (PPRIME.EQ.0) GOTO 60
          DO 5 I=1,PPRIME
          ALPHA(I)=0.
    5     CONTINUE
   60     PPP1=PPRIME+1
```

```
      DO 6 I=PPP1,N
      ALPHA(I)=X(I)
      IF (PPRIME.EQ.0) GOTO 620
      DO 61 J=1,PPRIME
      H=I-J
      ALPHA(I)=ALPHA(I)-PHIP(J)*X(H)
  61  CONTINUE
 620  IF (QPRIME.EQ.0) GOTO 6
      DO 62 J=1,QPRIME
      H=I-J
      IF (H.GT.0) ALPHA(I)=ALPHA(I)+THETAP(J)*ALPHA(H)
   62 CONTINUE
   6  CONTINUE
*                      2. CALCULATE NOISE COVARIANCE
      ALFBAR=0
      ALFSQ=0
      DO 7 I=PPP1,N
      ALFBAR=ALFBAR+ALPHA(I)
      ALFSQ=ALFSQ+ALPHA(I)*ALPHA(I)
   7  CONTINUE
      ALFBAR=ALFBAR/(N-PPP1)
      ALFSQ=ALFSQ/(N-PPP1)
      CALAL0=ALFSQ-ALFBAR*ALFBAR
*                      3.CALCULATE CROSSCORRELATION
      CALA0=0.
      V1=MAX0(SDP1,PPRIME+1)
      DO 8 I=V1,N
      CALA0=CALA0+(ALPHA(I)-ALFBAR)*(A(I)-ABAR)
   8  CONTINUE
      CALA0=CALA0/(N-V1+1)
      DENOM=SQRT(CALAL0*CAA0)
      RALA0=CALA0/DENOM
      QCHISQ=RALA0*RALA0
      DO 9 I=1,K
      CALA(I)=0
      NMINK=N-I
      DO 91 J=V1,NMINK
      H=I+J
      CALA(I)=CALA(I)+(ALPHA(J)-ALFBAR)*(A(H)-ABAR)
  91  CONTINUE
      CALA(I)=CALA(I)/(N+1-V1)
      RALA(I)=CALA(I)/DENOM
      QCHISQ=QCHISQ+RALA(I)*RALA(I)
   9  CONTINUE
      QCHISQ=(N-V1+1)*QCHISQ
      QDF=K-R-S
      RETURN
      END
*   SUBPROGRAM TO PRINT OUT STATISTICS
*
    SUBROUTINE OUTPT7(NBETA,NRESID,RESID)
*
```

```
      COMMON/PARAM1/IDUMMY(5),N,K
+              /STAT/VAROFA,COVMAT,STDDEV,CORREL,RAA,PCHISQ,PDF,RALA0,
+                     RALA,QCHISQ,QDF
      INTEGER N,K,PDF,QDF,NBETA,NRESID,RES1ST
      REAL VAROFA,COVMAT,STDDEV,CORREL,RAA,PCHISQ,RALA0,RALA,QCHISQ,RESID
      DIMENSION COVMAT(10,10),STDDEV(10),CORREL(10,10),RAA(30),RALA(30),
+                RESID(50)
      WRITE(9,100) VAROFA
  100FORMAT(19H RESIDUAL VARIANCE:,F10.3)
      WRITE(9,200)
  200 FORMAT(28H ESTIMATE COVARIANCE MATRIX:)
      CALL MATOUT(NBETA,1)
      WRITE(9,300)(STDDEV(I),I=1,NBETA)
  300 FORMAT(30H ESTIMATE STANDARD DEVIATIONS:,10(/,F10.3))
      WRITE(9,400)
  400 FORMAT(29H ESTIMATE CORRELATION MATRIX:)
      CALL MATOUT(NBETA,2)
      RES1ST=N-NRESID+1
      WRITE(9,500)(RESID(I),I=RES1ST,N)
  500 FORMAT(11H RESIDUALS:,65(/,F10.3))
      WRITE(9,600)(RAA(I),I=1,K)
  600 FORMAT(26H RESIDUAL AUTOCORRELATION:,30(/,F10.3))
      WRITE  (9,700)PCHISQ,PDF
  700 FORMAT(29H AUTOCORRELATION CHI-SQUARE:  ,F10.3,2H (,I3,6H D.F.))
      WRITE(9,800) RALA0,(RALA(I),I=1,K)
  800 FORMAT(33H INPUT-RESIDUAL CROSSCORRELATION:,31(/,F10.3))
      WRITE(9,900) QCHISQ,QDF
  900 FORMAT(30H CROSSCORRELATION CHI-SQUARE:  ,F10.3,2H (,I3,6H D.F.))
      RETURN
      END
      SUBROUTINE MATOUT(DIM,SWITCH)
*
*   COMMON VARIABLES* COVMAT - COVARIANCE MATRIX FOR ESTIMATES
*                          R - CORRELATION MATRIX FOR ESTIMATEN
      COMMON /STAT/DUMMY0,COVMAT,DUMMY(10),R
      INTEGER DIM,SWITCH,I,J,MIN,MAX
      REAL COVMAT,R,MATRIX
      DIMENSION COVMAT(10,10),R(10,10),MATRIX(10,10)
      IF (SWITCH.EQ.2) GOTO 20
*                       TO PRINT COVARIANCE MATRIX
   10 DO 11 I=1,DIM
      DO 1 J=1,DIM
      MATRIX(I,J)=COVMAT(I,J)
    1 CONTINUE
   11 CONTINUE
      GOTO 30
   20 DO 21 I=1,DIM
      DO 2 J=1,DIM
      MATRIX(I,J)=R(I,J)
    2 CONTINUE
   21 CONTINUE
```

UTES (Cont'd)

```
 30  IF (DIM.GT.7) GOTO 40
*                          IF 1 ROW WILL FIT ON 1 LINE
    DO 35 I=1,DIM
     WRITE(9,100) (MATRIX(I,J),J=1,DIM)
 35 CONTINUE
100 FORMAT(7F10.3)
     RETURN
*                          IF 1 ROW WILLNOT  FIT ON 1 LINE
 40  DO 41 I=1,DIM
     WRITE(9,200) (MATRIX(I,J),J=1,7)
200 FORMAT(7F10.3)
     MIN=1
     MAX=7
 50  MIN=MIN+7
     MAX=MAX+7
     IF (MAX.GE.DIM) GOTO 60
     WRITE(9,300) (MATRIX(I,J),J=MIN,MAX)
300 FORMAT(2X,7F10.3)
     GOTO 50
 60  WRITE(9,300) (MATRIX(I,J),J=MIN,DIM)
 41  CONTINUE
     RETURN
     END
```

Matrix Inversion Subprogram - MATINV

```
      SUBROUTINE MATINV(ISOL,IDSOL,NR,NC,A,NRA,KWA,DET)
*
*       WHERE:
*
*       ARGUMENT         USE          DESCRIPTION
*
*        ISOL           OUTPUT        COMMUNICATION FLAG:
*                                     =1  INVERSE FOUND OR EQUATION SOLVED
*                                     =2  UNABLE TO SOLVE
*                                     =3  INPUT ERROR
*
*        IDSOL          OUTPUT        DETERMINANT CALCULATION FLAG
*                                     =1  DID NOT OVERFLOW
*                                     =2  DID OVERFLOW
*
*        NR             INPUT         NUMBER OF ROWS OF INPUT MATRIX A
*
*        NC             INPUT         ABSOLUTE VALUE IS NUMBER OF COL. OF A
*
*                                     IF NC<=NR NO SIMULTANEOUS EQUATION
*                                     WILL BE SOLVED.  IF NC IS NEGATIVE
*                                     NO INVERSE WILL BE FOUND.
*
*        A              INPUT         INPUT MATRIX.  FIRST NR COLUMNS
*                                     FORM SQUARE MATRIX TO BE INVERTED.
*                                     NEXT (NC-NR) COLUMNS ARE CONSTANT
*                                     COLUMNS FOR (NC-NR) DIFFERENT SETS
*                                     OF SIMULTANEOUS EQUATIONS
*
*                       OUTPUT        RESULT MATRIX.  FIRST NR COLUMNS
*                                     FORM INVERSE IF INPUT NC IS POSITIVE.
*                                     NEXT (NC-NR) COLUMNS ARE CORRESPONDING
*                                     SOLUTIONS TO THE INPUT SIMULTANEOUS
*                                     EQUATIONS SETS.
*
*        NRA           INPUT          NUMBER OF ROWS RESERVED FOR MATRIX A
*                                     IN DIMENTION STATEMENT IN MAIN PROG.
*
*        KWA           WORK           WORK ARRAY OF FORM KWA(NR).  IF NC
*                                     IS NEGATIVE, KWA MAY BE A DUMMY VARIABL
*
*        DET            OUTPUT        VALUE OF DETERMINANT IF ISOL=IDSOL=1.
*
*
*  THIS SUBROUTINE FINDS THE INVERSE AND/OR SOLVES
*  SIMULTANEOUS EQUATIONS, OR NEITHER , AND
*  CALCULATES A DETERMINANT OF A REAL MATRIX.
```

MATINV (Cont'd)

```
*
DIMENSION A(1),KNA(1)
INTEGER OVERFL
 IR = NR
 ISOL = 1
 IDSOL = 1
 IF(NR.LE.0) GO TO 330
 IF((IR-NRA).GT.0) GO TO 330
 IC = IABS(NC)
 IF ((IC - IR).LT.0) IC = IR
 IBMP = 1
 JBMP = NRA
 KBMP = JBMP + IBMP
 NES = IR*JBMP
 NET = IC*JBMP
 IF(NC) 10,330,20
 10 MDIV = JBMP + 1
 IRIC = IR - IC
 GO TO 30
 20 MDIV = 1
 30 MAD = MDIV
 MSER = 1
 KSER = IR
 MZ = 1
 DET = 1.0
 40 PIV = 0.
 I = MSER
 50 IF ((I - KSER).GT.0) GO TO 70
 IF((ABS(A(I))-PIV).LE.0.) GO TO 60
 PIV = ABS(A(I))
 IP = I
 60 I = I + IBMP
 GO TO 50
 70 IF(PIV.EQ.0.) GO TO 340
 IF(NC.LT.0) GO TO 80
 I = IP-((IP - 1)/JBMP)*JBMP
 J = MSER - ((MSER - 1)/JBMP)*JBMP
 JJ = MSER/KBMP + 1
 II = JJ + (IP - MSER)
 KNA(JJ) = II
GO TO 90
 80 I = IP
 J = MSER
 90 IF (IP - MSER) 330,120,100
 100 IF ((J - NET).GT.0) GO TO 110
 PSTO = A(I)
 A(I) = A(J)
 A(J) = PSTO
 I = I + JBMP
 J = J + JBMP
 GO TO 100
```

MATINV (Cont'd)

```
110 DET = - DET
120 PSTO = A(MSER)
DET = DET*PSTO
IVF=OVERFL(DUMMY)
GO TO (130,140),IVF
130 IDSOL = 2
IF(PSTO.EQ.0.) GO TO 150
140 PSTO = 1./PSTO
GO TO 160
150 IDSOL = 3
ISOL = 2
RETURN
160 CONTINUE
A(MSER) = 1.0
I = MDIV
170 IF((I - NET).GT.0) GO TO 180
A(I) = A(I)*PSTO
I = I + JBMP
GO TO 170
180 IF((MZ - KSER).GT.0) GO TO 210
IF((MZ-MSER).EQ.0) GO TO 200
I = MAD
J = MDIV
PSTO = A(MZ)
IF(PSTO.EQ.0.) GO TO 200
A(MZ) = 0.
190 IF((J-NET).GT.0) GO TO 200
A(I) = A(I) - A(J)*PSTO
J = J + JBMP
I = I + JBMP
GO TO 190
200 MAD = MAD + IBMP
MZ = MZ + IBMP
GO TO 180
210 IVF=OVERFL(DUMMY)
GO TO (350,220),IVF
220 KSER = KSER + JBMP
IF ((KSER-NES).GT.0) GO TO 260
MSER = MSER + KBMP
IF(NC.LT.0) GO TO 230
MDIV = MDIV + IBMP
MZ = ((MSER - 1)/JBMP)*JBMP + 1
MAD = 1
GO TO 40
230 MDIV = MDIV + KBMP
IF(IRIC.NE.0) GO TO 240
MZ = MSER + IBMP
GO TO 250
240 MZ = ((MSER - 1)/JBMP)*JBMP + 1
250 MAD = MZ + JBMP
GO TO 40
```

MATINV (Cont'd)

```
 260 IF(NC.LT.0) RETURN
 JR = IR
270 IF(JR) 330,360,280
 280 IF(KWA(JR) - JR)330,320,290
 290 K = (JR - 1)*JBNP
 J = K + IR
 L = (KWA(JR) - 1)*JBNP + IR
 300 IF(J - K)330,320,310
 310 PSTO = A(L)
 A(L) = A(J)
 A(J) = PSTO
 J = J - IBNP
 L = L - IBNP
 GO TO 300
 320 JR = JR - 1
 GO TO 270
 330 ISOL = 3
 RETURN
 340 DET = 0.
 ISOL = 2
 IDSOL = 1
 RETURN
 350 ISOL = 2
 IDSOL = 2
360 RETURN
 END
```